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THE OCTOBER SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

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THE SCIENTIFIC MONTHLY

OCTOBER, 1932

HEREDITY AND ENVIRONMENT—AS ILLUSTRATED BY TRANSPLANT STUDIES¹

By Dr. H. M. HALL

In the announcement of this address the main title has been set down as "Heredity and Environment"; but since I have myself entered the field from the side of taxonomy I ask your permission to begin with this topic and after having outlined the aims of taxonomy and its relation to studies in evolution, to present some results of experiments on effects of heredity and environment, which two factors lie at the very basis of all evolutionary and taxonomic studies.

THE PLACE OF TAXONOMY

Taxonomy, in the biological sense, is the classification of animals and plants according to their natural relationships and deals also with the laws and principles of such classification. Classification itself may be based entirely upon resemblance or upon any other convenient set of criteria and so may be entirely artificial.

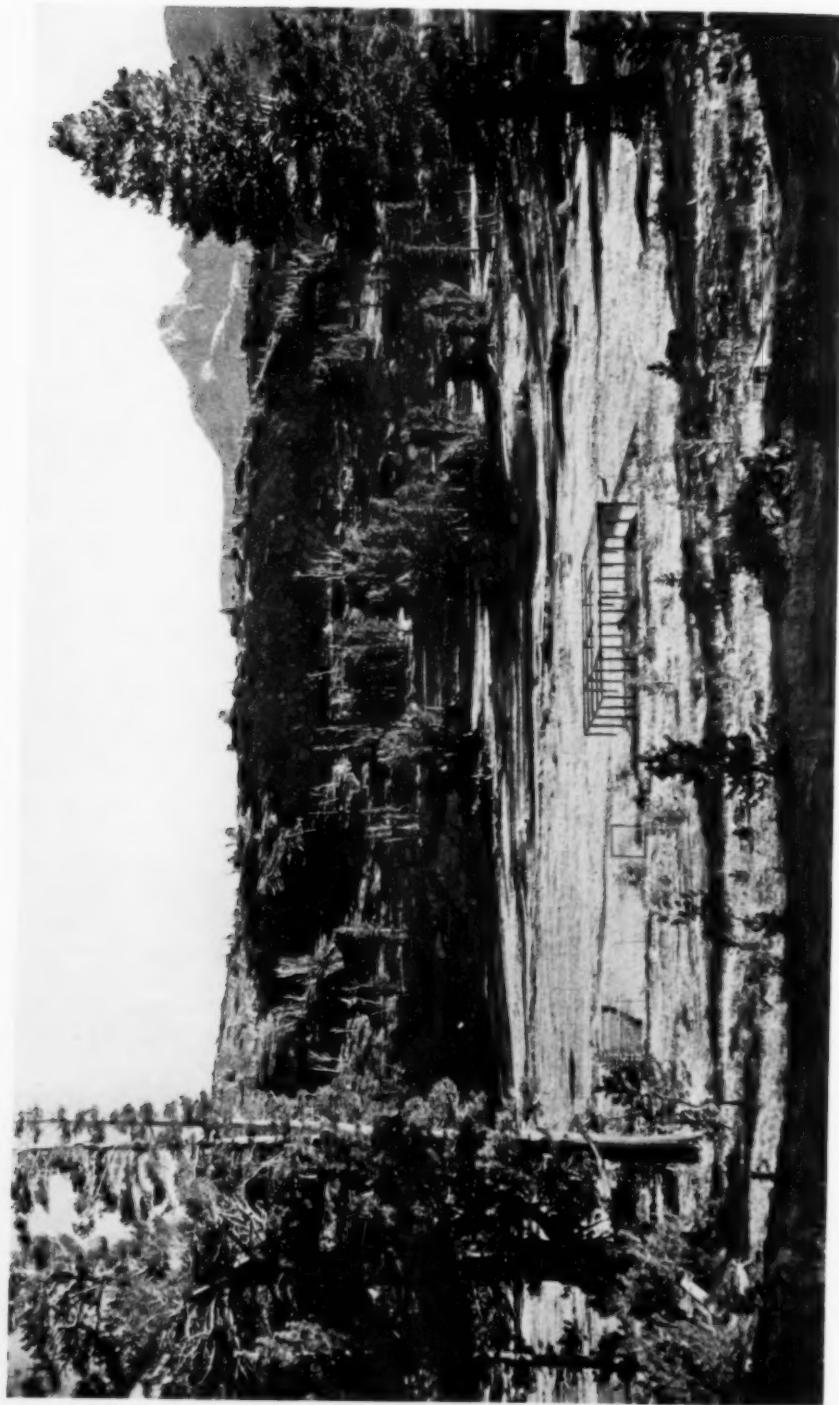
The earliest phase of biological science, so far as we are able now to determine, was the outcome of early man's attempt to classify according to similarities and uses. We find, for example, such a classification in the works of

¹ Prepared for the lecture series of Carnegie Institution of Washington. Due to illness of the late Dr. Hall, it was delivered on December 4, 1931, by Dr. Walter T. Swingle, Bureau of Plant Industry, U. S. Department of Agriculture.

Aristotle, and the mere fact that this early philosopher and biologist sometimes placed marine animals and plants in the same category, because of morphologic resemblance, does not diminish our admiration for his keen insight nor our appreciation of the impetus he and his students gave to the science of classification.

As time went on, the analysis of plant (and animal) characters became more and more refined, and this in turn led to a more and more rational system and to the development of true taxonomy, that is, a classification based upon natural relationship. The idea of evolution also must have had some influence upon classification long before Darwin's time, for even Aristotle pointed out the "unbroken chain" from the lowest forms of life to the highest. But, however this may be, it was not until after the publication of the "Origin of Species" that taxonomists attempted an arrangement based definitely upon the theory of relationship by descent.

It was this coming in of the concept of evolution that gave a new significance and new life to the subject of taxonomy. Up to that time it had been pursued chiefly by physicians and others who recognized the practical value of classification, and by those who, like Linnaeus, were interested in the study for its own sake; but when it became evi-



A VIEW IN THE TRANSPLANT GARDENS AT TIMBERLINE STATION, ELEVATION 10,000 FEET.

dent that these more or less natural groups of organisms were the product of evolutionary processes and that each possessed, therefore, a definite although perhaps indefinable blood relationship to every other, it naturally followed that taxonomy took its place as one of the most valuable tools for the student of evolution.

We must not, however, lose sight of the facts that evolution still is a theory, that any classification based upon this theory must be of necessity speculative in its nature and that it will approximate the truth only in proportion to the number of established facts upon which it rests. But the vital point here is that if there be anything at all to organic evolution, then taxonomy is dealing with the products of evolution and it is this that gives to taxonomy both its highest mission and its greatest responsibility.

In the planning of any thorough investigation the first step is to make a survey of the field and to organize the stock of facts already at hand. It is this survey which taxonomists are making and which they offer to the student of evolution; it is an enumeration of the countless forms of life arranged according to natural relationships, so far as these can be determined from available evidence.

But a still more important duty falls to the taxonomist. He, more than any one else, should be intimately informed as to the distribution and the arrangement in nature of the products of evolution—the families, genera, species and especially the subdivisions of species—and hence should be expected to correlate the findings of both speculative and experimental evolutionists with the results of his own field investigations. No theory of evolution or of origin of species can be finally accepted until it explains the origin of the many forms of life as they exist in a natural state.

Thus taxonomy may be said to stand

both at the beginning and at the end of the long series of studies on evolution; at the beginning it furnishes the survey and the inventory of evolutionary units; at the other extreme it checks results against the inexorable requirements of the facts of nature.

NEW METHODS IN TAXONOMY

The conclusions of taxonomy result largely from observation, description and comparison; in other words, they are reached subjectively. There is now an ever-increasing movement to introduce objective methods, especially for the testing of criteria used as a basis for classification. Thus we have application of statistical methods, the methods of serum diagnosis and of biochemistry. Genetics and cytology, although organized for a different purpose, supply incontrovertible facts as to the nature of plant characters.

But this evening I have the privilege of calling to your attention a quite different method for testing the criteria of taxonomy. This we refer to commonly as the transplant method, although I must warn you that it is not to be confused with transplant experiments devised for very different purposes.

The object of the experiments now to be described is not to demonstrate the evolution of one hereditary form from another and much less the origin of one species from another; although it is conceivable that out of them may come evidence bearing upon these important questions of heredity and evolution. They are designed, instead, to furnish definite evidence as to the nature of certain plant characters and the value of these as criteria in plant classification.

TRANSPLANT METHOD IN TAXONOMY

From this experimental study of plant characters, however, there come results of interest in fields other than taxonomy. These various issues may be

grouped under three general heads, which I shall now briefly enumerate, with some hint as to methods, and then pass to illustrations of the results obtained and incidentally bring out more clearly some of the methods used in arriving at these results.

As the first outcome of present transplant experiments may be mentioned the ability to distinguish between those variations which are not heritable and those which are—*i.e.*, between those temporary modifications that result from the immediate environmental impact and those other features so fixed by heredity that they can not be changed by the environment; or again, between phenotypes on the one hand and genotypes on the other.

On the other hand, the differences persist in the standard environment, they are known to be of a genotypic nature and hence of evolutionary significance.

The second group of returns flowing from the transplant experiments supplies information as to the extent to which the habitat may modify plant characters without necessarily affecting the genotypic constitution. This knowledge is of prime importance both to taxonomy and ecology and is best obtained by moving an individual plant into as many different habitats as possible (Fig. 1).

This is easily accomplished with perennials subject to vegetative division; for these divisions may be grown simultaneously at the seashore, in interior



FIG. 1. PROFILE OF THE AREA IN WHICH TRANSPLANT STATIONS ARE LOCATED WITH ELEVATIONS INDICATED IN FEET ABOVE SEA-LEVEL. FROM LEFT TO RIGHT: PACIFIC OCEAN; MONTARA STATION; CENTRAL LABORATORY AND GARDENS AT STANFORD UNIVERSITY; BREAK IN LINE INDICATES THE WIDE SAN JOAQUIN VALLEY; MATHER STATION IN THE SIERRA NEVADA; CREST OF THE SIERRA AT 12,500 FEET; TIMBERLINE STATION (T. L.); AND THE MONO STATION IN THE ARID GREAT BASIN.

For this determination the practiee is to select individual plants of the same species, or of closely related species, but which differ in those features which it is desired to test. These individuals are then moved from their diverse habitats into a standard environment, where they are held for some years, under control and under close observation. If, then, the differences vanish, the two forms are shown to be but temporary environmental modifications; but if, on the

valleys, at various altitudes in the mountains, in sun and in shade, in moist and in dry soil, and, in fact, the original individual may thus be subjected to as great a variety of environments as one's facilities will permit. In practice, the only restriction is avoidance of conditions to which plants are not subjected in nature, for teratological effects are here to be avoided. The results are best studied by taking photographs and specimens from all the divisions and

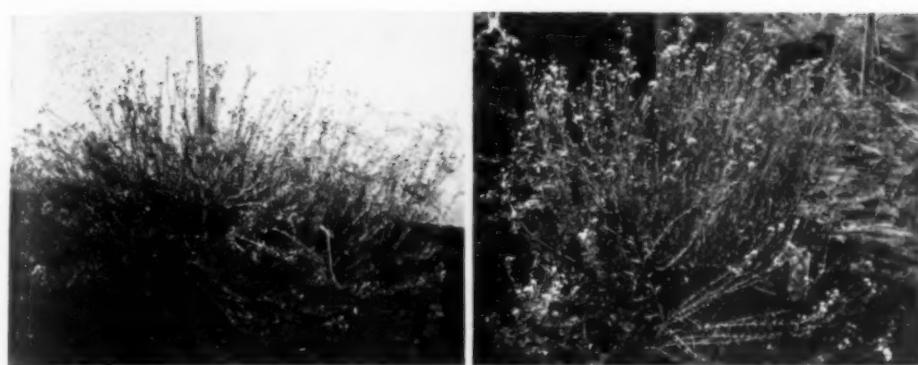


FIG. 2. MODIFICATIONS IN THE HABIT OF *HAPLOPAPPUS VENETUS*

THESE INDIVIDUALS ARE NOW GROWING TOGETHER IN THE GARDEN. IN ITS NATIVE HABITAT THE PLANT ON THE LEFT WAS DECUMBENT, THE PLANT ON THE RIGHT WAS ERECT. THE FORMER HAS NOW BECOME AS ERECT AS THE LATTER, WHICH HAS REMAINED UNCHANGED.

comparing these between themselves and with a specimen of the original, preserved as a control.

With information at hand as to the heritable nature of the characters of any plant and also as to the extent to which environment may modify these characters in the individual, it is seen very plainly that each organism is the resultant of two important forces, namely, heredity and environment. In fact,

each organism, as we see it, is the result of or balance between these two opposing forces. This vision of the organism as a balance is most forcibly impressed upon one engaged in transplant experiments.

The third result of these experiments is a better knowledge of the composition of species and genera. The assembling of natural variations necessitates much detailed field exploration with its re-



FIG. 3. THREE TYPES OF *ZAUSCHNERIA*

DIFFERING PRINCIPALLY IN LEAF-WIDTH. FROM LEFT TO RIGHT THESE ARE: *Z. latifolia*, *Z. californica* AND *Z. microphylla*.



FIG. 4. MODIFICATION ON A SINGLE SHOOT OF *ZAUSCHNERIA*

LOWER, NARROW LEAVES RESEMBLE THOSE OF ORIGINAL FORM AT LOMPOC, CALIFORNIA. THESE WERE PRODUCED WHILE PLANT WAS GROWN AT A COASTAL STATION. UPPER, BROAD LEAVES WERE PRODUCED AFTER TRANSPLANTING TO DRY SHADE AT MATHER, CALIFORNIA. THE LOWER LEAVES WOULD CLASSIFY THE PLANT AS *Z. californica*; THE UPPER ONES AS *Z. latifolia*.

sultant information as to number of forms involved, their ecologic relations and their geographic distribution at the present time. The assembling of these variations into standard environments at one or more of the transplant stations encourages one to make direct comparisons between them after they have been stripped of all differences brought about by the immediate effect of their former habitats. In this manner there is obtained definite information as to relative length of steps between the forms. This information can not be gained by other means of investigation.

In summarizing to this point, it may be said that experiments have been devised and put into operation which lead to a better understanding of plant characters and forms, especially through the means they furnish, first, of distinguishing between effects of heredity and environment and for recognizing the balance between these two forces, and, second, for determination of the extent to which environment may modify heritable features. Through use

of these results and from data obtained from geographic distribution there is derived a knowledge of the ecologic and genetic units constituting species and genera.

The general result from experiments and field studies thus far made in California has emphasized the fact that within many species there is a vastly larger number of heritable variations (genotypes, ecotypes, races, etc.) than has been assumed and that the classification of these can not be satisfactorily made by current methods of taxonomy. On the other hand, it is found that environment plays a large part in molding the organism within the limits set by hereditary factors. Although no evidence has been found to prove that environmental forces may induce permanent (genotypic) change, there is no reason to exclude this as a possible factor in evolution.

ILLUSTRATIONS OF THE METHOD

As examples directly applicable to classification, there may now be cited

two sets of experiments which helped to determine the taxonomic status of certain forms of *Haplopappus*, a genus of the *Compositae* which I myself had the temerity to monograph before this experimental evidence was available. One of these experiments illustrates also the effect of heredity in holding plant characters within bounds; while the other illustrates the importance of environment in making modifications within these hereditary boundaries.

The subject of the first experiment is *Haplopappus squarrosus*, which has two forms. One nomenclatorily typical, but rather rare, grows only near the sea. The other is an inland form and much more common. In my monograph the differences were noted from herbarium and field studies, but taxonomic segre-

gation was avoided for fear that the coastal form might be merely a maritime variation. Since publication, both forms have been brought to a standard environment where they have not only maintained the differentiating characters (five years), but have permitted detection of differences previously overlooked. The results call for separation, at least into subspecies.

Quite different was the case of two forms of *H. venetus*. This shrub is commonly and typically erect. On certain soils, however, it occurs in a decumbent or nearly prostrate form, so different in appearance that it was technically named as a distinct species (*decumbens*), by an earlier taxonomist. This decumbent form when brought into the experimental garden assumes a habit

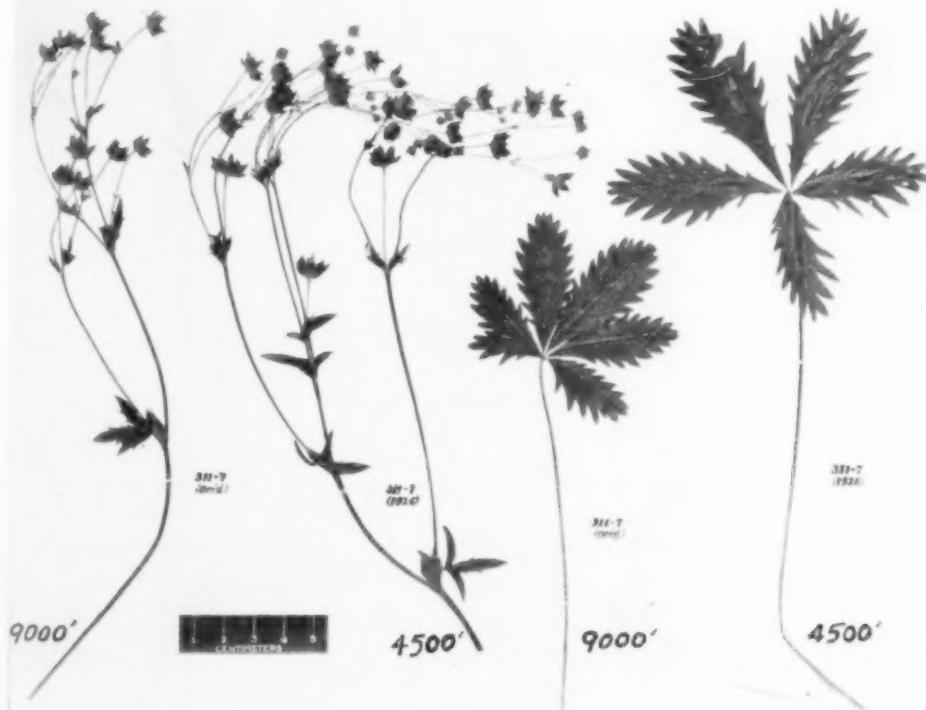


FIG. 5. *POTENTILLA GRACILIS*
AT 9,000 AND AT 4,500 FEET. INFLORESCENCE AND LEAVES INCREASE IN SIZE WHEN PLANTS ARE
MOVED DOWN THE MOUNTAINS. (ALL ARE PARTS OF THE SAME ORIGINAL PLANT.)

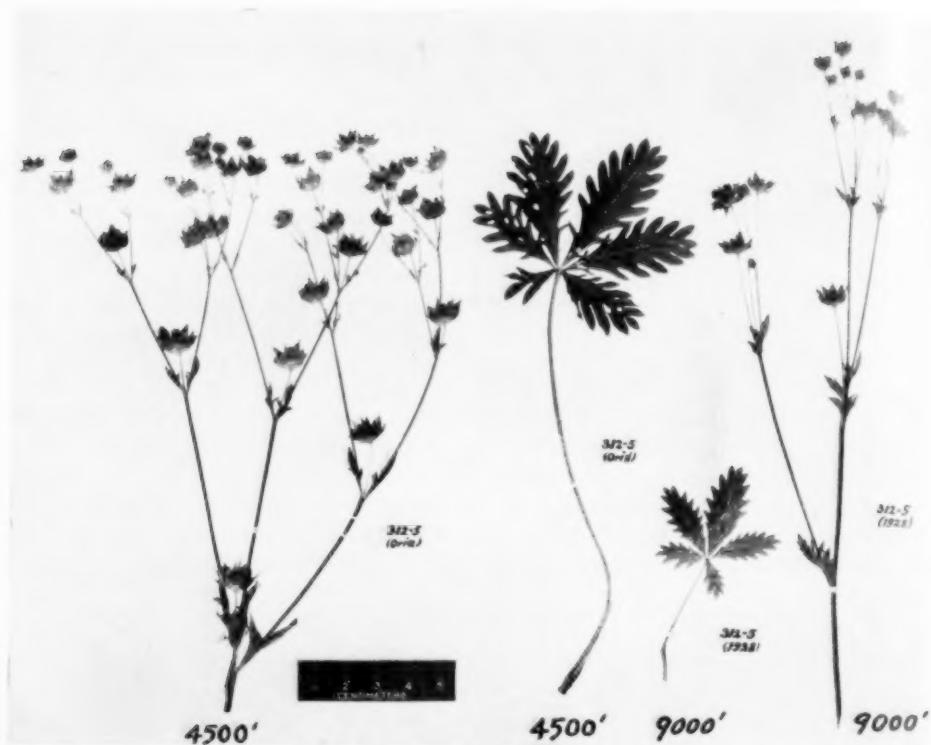


FIG. 6. *POTENTILLA GRACILIS*
AT 4,500 FEET AND AT 9,000 FEET. INFLORESCENCE AND LEAVES DECREASE IN SIZE WHEN PLANTS
ARE MOVED UP THE MOUNTAINS. (ALL ARE PARTS OF THE SAME ORIGINAL PLANT.)

as strictly erect as that of the common form growing beside it in the cultures.

Thus these simple though time-consuming experiments lead to definite conclusions as to the nature of the characters in question and leave no doubt as to the taxonomic treatment of the forms involved.

Now in order further to illustrate methods for distinguishing with certainty between hereditary and environmental forms, we come to a most interesting as well as beautiful genus of western American plants. Even the name holds our interest, although it can not be said to be beautiful, for the genus is *Zauschneria*, a member of the evening primrose family, named in 1831 in honor of the Bohemian botanist, Zauschner.

In our investigations to date, 134 of these hereditary types have been discovered and many times this number may be expected from future exploration. All these 134 types have been transplanted to a testing garden at Stanford University, and there, under a common environment, each is found to retain its peculiar characteristics.

If the most unlike forms are compared the differences are so great as to lead one to look upon them as distinct species; but when all are arranged in a single series the steps separating each from its neighbors are so slight that it is impossible to assign them to different groups. In this case heredity sets very narrow limits so that changes in the environment have little effect.

The influence of the habitat in mold-

ing plant characters is also illustrated with *Zauschneria*. Some botanists have proposed that as many as 22 species should be made in the genus, while others, more conservative, have proposed three as the correct number. If three are accepted, these would be *latifolia*, with broad leaves, *californica*, with leaves of intermediate width, and *microphylla*, in which the leaves are very narrow. But these differences may be due to environment and not to heredity, for plants with moderately wide leaves (*californica*) have been moved into partly shaded gardens where they produced leaves so wide that the plants would thereafter be classed as *latifolia*, and similar modifications have been induced in other forms.

The investigations in *Zauschneria* have not been designed to give a conclusive answer to the very debatable question

as to whether modifications induced by the environment may become hereditary in time. But thus far no changes have been induced by environmental conditions which have the appearance of becoming hereditary.

Potentilla rupestris is another widespread species whose representatives in the western United States have been subjected to transplant experimentation for several years. From the one hundred and sixty or so members of this Linnean "species" that have been assembled for study, at least sixty-five genetically distinct forms have been detected.

Another member of this genus, *Potentilla gracilis*, may be used to illustrate the methods employed in making reciprocal transplants. A plant was moved from 9,000 feet down to 4,500 feet in the Sierra Nevada. This did not

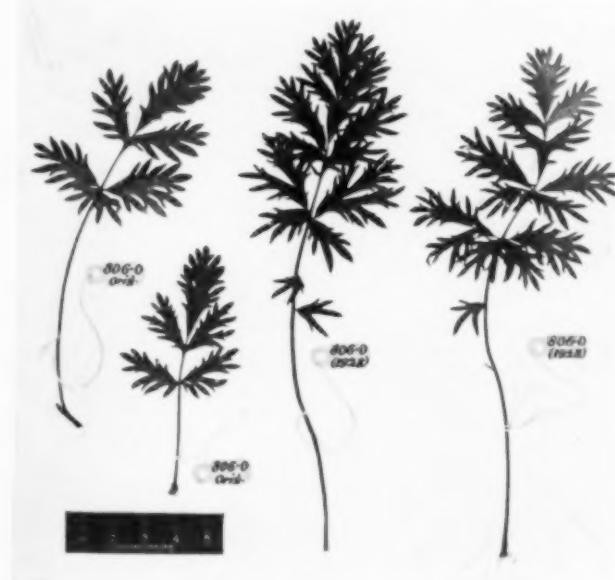


FIG. 7. *POTENTILLA BREWERI*

SHOWING INCREASE IN NUMBER OF LEAFLETS AND OF INCISIONS. THE TWO LEAVES AT LEFT ARE AVERAGE ONES TAKEN FROM THE PLANT IN ITS ORIGINAL HABITAT AT 9,000 FEET ALTITUDE (1923). THE TWO LEAVES AT RIGHT ARE AVERAGE ONES TAKEN FROM A DIVISION OF THE SAME PLANT THAT PRODUCED THE ONES AT LEFT, BUT AFTER IT HAD BEEN TRANSPLANTED TO AN ALTITUDE OF 4,500 FEET (1928).



FIG. 8. DISTRIBUTION OF THE FORMS OF *HEMIZONIA PANICULATA*

A. SOUTHERN SUBSPECIES, SOUTHERN AND LOWER CALIFORNIA—(a) THE MOST SLENDER FORM: FIXED, AS SHOWN BY EXPERIMENT; (b) A LESS SLENDER FORM: FIXED, AS SHOWN BY EXPERIMENT. B. NORTHERN SUBSPECIES, SANTA BARBARA TO MONTEREY. INSERT CIRCLE SHOWS PART OF ITS AREA ON A LARGER SCALE; (a) INTERIOR, EIGHT-RAYED FORM (INDICATED BY CIRCLES); (b) COASTAL, THIRTEEN-RAYED FORM (INDICATED BY DISCS); (c) HYBRID COLONIES (INDICATED BY CROSSES).

change the number of leaflets or of dentations, but it did greatly increase the number of flowers and consequently of seeds and offspring, as shown in Fig. 5. That this was not due merely to better conditions in the garden was shown by the results in the reciprocal transplant. An individual of the same species originally growing at 4,500 feet was moved to the exact habitat of the former at 9,000 feet. The effects of this change on the parts was to decrease the number of flowers, while the number of leaflets

and of dentations remained constant, Fig. 6.

In another species, *Potentilla breweri*, however, it was possible to modify the number of leaflets by moving an individual from 9,000 feet to 4,500 feet, as is shown in Fig. 7.

MODIFICATION OF NATIVE VEGETATION

Some of the most interesting results have been obtained with the common California tarweeds. These are mem-

bers of the subtribe *Madinae* of the *Compositae*. When grown side by side at the transplant station these show amazing diversity in size, method of branching and general appearance, in spite of being grown under identical soil and climatic conditions. That these are not among our attractive wild flowers there can be no doubt, and perhaps the question has arisen in your minds as to why these homely weeds were selected for the experiments. This was partly because they are so abundant in the region where we happen to be located, partly because they can easily be grown from seed, partly because they are so plain and useless that man has not mixed the breeds in an attempt to improve them; but most of all it was because some of the species grow only in alkaline soil and around salt marshes

where they have escaped the encroachment of civilization. Thus far man has been too busy modifying and destroying the native vegetation on areas suitable for browsing, grazing, agriculture or subdivision into town lots to concern himself with these inhabitants of unattractive corners of his domain.

It is remarkable that even in the West it is almost impossible for the biologist to find undisturbed areas for his investigations or to select a group of organisms in which all the forms still exist in their original condition. When one attempts to trace evolutionary lines, every connecting variation is of the utmost significance. It is therefore necessary, even with these tarweeds, to select groups where the lines have not been broken, and too often these can be found only in species of the alkaline



GREENHOUSE WITH TARWEEDS AT THE CENTRAL STATION OF THE DIVISION OF PLANT BIOLOGY, CARNEGIE INSTITUTION OF WASHINGTON.

wastes or in those which by chance may be present in such desolate places as the old neglected cemeteries; and, if one is to judge from man's present progress in the desecration of nature, the biologist of the future will be fortunate indeed if he be permitted access even to the alkali flat and the cemetery.

As an example of the modification on the native vegetation caused by man, attention may here be called to one group of tarweeds (*Hemizonia villosa* and its relatives), which formerly occupied arable soils of the California valleys, as evidenced by specimens preserved in herbaria and by a few plants still living in out-of-the-way corners. But some of the variations represented in the collections of early botanical explorers are no longer to be found, and doubtless many others no longer exist-

tent were overlooked by those pioneer botanists. After 20 years of search it has been decided that the gaps are too great to justify even a speculative reconstruction of evolutionary lines. It is possible that by genetic analysis of the remaining forms and the building up of new combinations through crossing, some clue might be had as to these lines, but the results would forever lack the confirmation which can come only from researches in taxonomy and geographic distribution.

STEPS IN THE EVOLUTIONARY PROCESSES

We turn to the consideration of results flowing from the experimental investigation of taxonomic units. It happens that the example now to be given clearly illustrates also the high



A CORNER OF THE TRANSPLANT GARDENS IN THE SIERRA NEVADA AT MATHER,
ELEVATION 4,500 FEET.

pioneer arch it are too tive re- nes. It ysis of building cross- o these er lack e only d gen- value to science of preservation of natural conditions. It concerns a species of *Hemizonia* which has persisted in, we hope, all its natural forms. It is *Hemizonia paniculata*, a species not hitherto suspected of having variations of evolutionary value. There are such variations, however. Although few, they are sufficient to indicate very concisely what are taken to be steps of varying lengths in the formation of species. A special virtue of this case is that the differences may be expressed in numbers, and the facts, if not the conclusion, may therefore be determined in an entirely objective manner.

By coupling experiment with field studies on this tarweed we gain a vision of species in the making or at least of the different degrees of separation between related forms within the species.

The situation is shown in the map of the coastal district of California (Fig. 8). One is at once struck with discontinuity in distribution. Over the considerable area from above Santa Barbara to Riverside, not a single plant of this species can be found, so that there is a definite barrier between plants of the north and those of the south. This distribution is correlated with differences in morphologic characters. The northern plants are the more robust and regularly have more disk-flowers than those of the south. These differences are retained when both are grown together in a standard environment.

Thus the species is geographically and morphologically separated into two subspecies with no intergradation.

More interesting from an evolutionary point of view are the smaller variations within each of these subspecies. For example, the southern subspecies has two forms, one slender and small-flowered, occurring in Lower California. The other, less slender, occurs north of the Mexican boundary. Since these are heritable forms, as experimen-

tally proven, we see that there has been an evolutionary segregation at about the line of the Mexican boundary.

But it is in the northerly subspecies that the most definite segregation has taken place, definite because capable of numerical expression. The difference lies in the number of ray-flowers. This has been determined at many localities, at each of which the number has been counted usually on 100 plants. On the map the circles indicate colonies where number of ray-flowers is regularly 8; the black discs where they are 13. At these localities there is no gradation from the one to the other. There is slight variation around 8 and 13, respectively, but no meeting or overlapping. The separation is complete.

But quite different is the situation at certain other localities, represented by the crosses. Here the number of ray-flowers centers around neither 8 nor 13, but varies between these extremes, with a majority approaching sometimes the one, sometimes the other. These colonies which link the 8-group and the 13-group are of much significance.

In full realization of the risk one runs in drawing conclusions from field observations, even when supported by garden experiments, as these have been, with these facts before us, we can at least glimpse something of the evolutionary processes which have been going on within this group of plants. As I see it, the steps were somewhat as follows:

First, the separation into two subspecies, a northern and southern, with a barrier between is very clear. Then the breaking up of the southern of these into smaller units is less clear-cut, owing perhaps to retention of contacts along the border. In the northern subspecies there has been a sharp segregation into two forms and a subsequent coming together of these at certain localities where, probably through hybridization,

there have been set up colonies which the taxonomist would class as "exactly intermediate."

BALANCE BETWEEN HEREDITY AND ENVIRONMENT

The various illustrations that have been given may serve to offer a glimpse of the complexity of forms as they occur in nature. Every plant and animal is the product of two very unlike and variable influences. One influence is that of its ancestors. This is heredity. The other comes from its home. This is environment. Heredity sets the limits of the influences of the environment. Environment decides the position within

these limits. Some traits for which heredity sets wide limits may be profoundly changed; others for which heredity sets very narrow limits may be changed only by changing the heredity itself through some process of breeding. In studying the history of the development of organisms on the earth by means of the classification of the products of evolution, it is of capital importance to know with certainty how far heredity controls and how far environmental conditions control the traits under consideration, for it is only through heredity that ancestral influences are expressed and evolutionary relationships are revealed.

THE ELUSIVE RUFFLE PLANT, RIELLA

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FOR almost a century, a ruffle standing on end has been playing an interesting game of hide-and-seek with the botanist. Elusive and sly, this anomalous plant has managed to keep out of the clutches of the scientist and, since it is too small to attract the attention of the layman, it has nothing to fear at his hands. Beautiful and shy, it has tried to escape to the four corners of the earth, only to be run down again by the heartless collector. And once found, it has on occasion used the tactics of a sly fox and managed to give up its habitat and thereby elude further search for several decades. The plant is still in the lead in the hide-and-seek game, and the botanist must be content with playing as best he can the poor hand which nature has given him out of a stacked deck.

One of the rarer of the several hundred thousand known plants, and certainly among the most anomalous in form and structure, this bright green ruffle nevertheless has one of the most prosaic of names—*Riella*, after Du Rieu de Maisonneuve, but suggesting a river or brooklet. True to its name, the first *Riella* to be seen by the writer was growing in the fresh waters of a creek in the Davis Mountains of western Texas. This stream, locally called Madera Creek, is hemmed in by very steep canyon walls hundreds of feet high and its waters run, now precipitously, now lazily, in a northeasterly snake-like path fifteen hundred feet below the summit of the adjacent Timber Mountain. During the summer rainy season they form a torrent for a few hours after a hard downpour; but during the greater part of the year they

trickle rather slowly over the intervening rocks and sand from one shallow pool to another, or else they disappear beneath the sands on leaving one pool only to reappear in a second one a hundred or two yards below. During the summer rains, the unbroken current can be traced from its source near Mount Livermore, also called Baldy Peak, which holds its head 8,382 feet above sea-level, for ten miles or so to the abrupt mouth of the canyon at an elevation of 4,500 feet, and then over the level, treeless plain. The latter part of the course is ordinarily a dry sandy and rocky creek bed, and in the ascent of the creek water can not be found until the shade of the high canyon walls retards the excessive evaporation so ruinous on the plain, and permits a good cover of grasses, shrubs and even trees.

It was in the shaded canyon of Madera Creek that *Riella* was first seen by the writer, forming a solid green mat extending from several inches below the water in a small, shallow pool on up the sandy bank to a distance of three feet beyond the water's edge. Here, evidently, was an aquatic plant which had been completely submerged during the several months when unusually heavy winter and spring rains had kept this little pool twice or thrice its present size. It was apparent, further, that during the last few days or weeks the water level in the pool had sunken, leaving the bulk of the beautiful green carpet, two inches in thickness, fully exposed to the air. Holding an individual plant, an inch or so in length, to the sun, it proved to be quite thin and transparent, leading one to infer that the carpet can not endure very long out

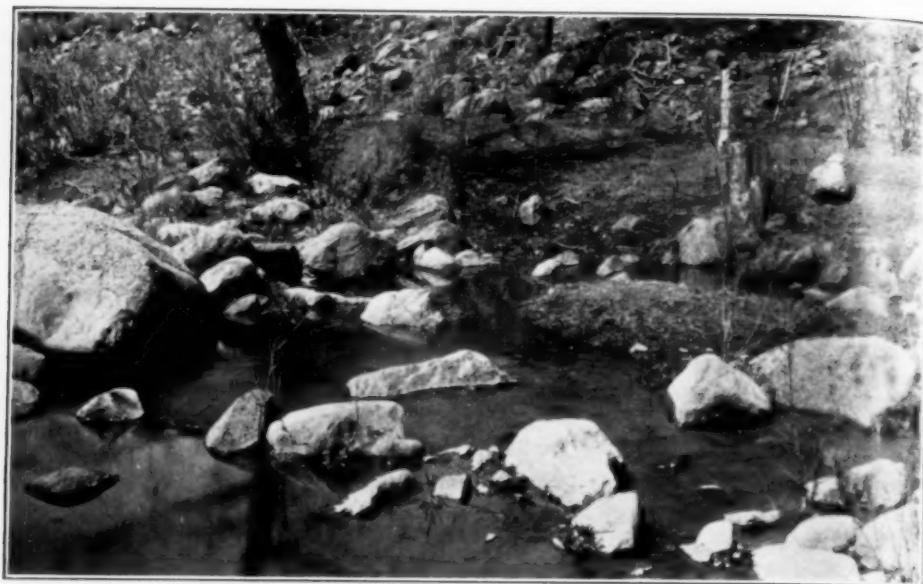


FIG. 1. A TYPICAL SHALLOW POOL OF MADERA CREEK
IN THE DAVIS MOUNTAINS OF WESTERN TEXAS, IN WHICH THE COMPLETELY SUBMERGED *Riella americana* WAS FOUND. PHOTOGRAPH BY PAUL D. VOTH.

of water, for the sand and gravel on which it was growing could not remain moist enough to supply the needed water for the simple system of rootlike hairs growing out from the base of the ruffle.

An accidental and unusual find, one must consider this; but what is this strange, green ribbon or ruffle standing on end, so unsymmetrical in appearance, with a thickened "stem" and a very thin "wing"? For the moment it was impossible to say with certainty even to which of the four major groups of plants this anomalous form belongs; but if one must guess, he would like to place it in the Bryophytes, among the liverworts. That this ignorance was not so inexplicably profound is indicated by the reaction of one of the best botanists in the country who stated, upon seeing our specimens, that he would hardly have recognized the plant as a liverwort.

On the same day the plant was found

in abundance submerged in other parts of the creek (Fig. 1); at no time in the five years following has it been seen to form a carpet outside of the water, and it has become less abundant every year. So far as known, this species, *Riella americana*, occurs at the present time only in the upper reaches of Madera Creek, from the mouth of the canyon toward its headwaters.

Our curiosity was aroused to determine how much was known of this rare plant, and to know something of its relatives. As known at the present time, the genus *Riella* is composed of not more than twelve species, which may prove to be a mere half dozen. The nearest geographical neighbor to the American species is the one found in the Canary Islands. Others occur in Algeria, Morocco, Tunis, Sardinia, Greece, Switzerland and France. Almost as far distant as Texas from this Mediterranean center of distribution are Turkestan and South Africa, each of which

harbors a single species. At the present time, Algeria leads, with four species.

These several species are so nearly alike that there is no question of their belonging together in a single genus, which is the only representative of the family Riellaceae. Although it is associated taxonomically with the family Sphaerocarpaceae, one may assert that *Riella* is structurally a much isolated plant. It is, indeed, so peculiar that the taxonomists have never agreed on its position in the plant kingdom. It has been shifted back and forth between the Marchantiales and the anaecrogynous Jungermanniales, or has been placed with *Sphaerocarpus* into a distinct primitive group, or more recently has been considered quite advanced and placed with the acrogynous Jungermanniales. Such shifting is the inevitable fate of all anomalous organisms.

A number of unusual situations have arisen in connection with the discovery of *Riella* in various parts of the world. The first known form was found by De Notaris in Sardinia in 1834. It appears that only a single collection was made and that there are no herbarium specimens in existence from this locality; we rely upon Montagne's rather imperfect description of the form. More than half a century later, Müller identified as this same species, *R. notarisi*, a single incomplete collection made in Greece in 1887. Otherwise, the species has succeeded completely in eluding the botanist.

This first known of the *Riellas* foreshadowed much of the future history of this remarkable genus. Virtually all the species are rare. *R. paulsenii* from Turkestan has been collected only once, and that under very strange circumstances, while several other species have become lost, only to be found again at a much later date. *R. reuteri* of Switzerland may be considered the classical example of a lost form. Discovered on the banks of the Lake of Geneva by

Reuter in 1851, it was collected at intervals for several years. Later a mill was erected over the single small muddy spot in which it had grown, and for decades the species eluded all search, both here and elsewhere. It is said that the Schloss Bartholoni now occupies the site. When rediscovered, it was again in possession of a very limited area further up the Rhone valley where, according to Meylen, it is once more in danger of being exterminated by the "improvements" of man. Fortunately, other *Riellas*, formerly considered distinct species but believed by Trabut to be morphological variations of *R. reuteri*, are present in France and northern Africa.

The French form was similarly lost for over twenty years, at which time it was found not only at its original site but in another location at some distance in the same province.

The American species was first described from a collection made in 1902 by Earle and Tracy in Limpia Creek in the Davis Mountains, although Schott had gathered some specimens of the plant in the same creek in 1855, and Saunders had made a single collection of it in South Dakota in 1898. Between 1855 and 1902 the plant was not seen in the Davis Mountains, and after the latter date it was once more lost until 1927. These losses may be attributed in part to the small number of botanists to visit this region; but this is not the only explanation, for between 1902 and 1927 the organism left its original home in Limpia Creek completely, either jumping across the mountain range to Madera Creek, or else being more successful in remaining in Madera, where it had not been seen until 1927. The plant has evidently disappeared from South Dakota, as it did from a temporary lake near Lubbock, Texas, where it was found for a single season. The American species has, then, become lost from three localities, and apparently is

present now only in Madera Creek; again, aside from the specimens obtained in Madera and near Lubbock since 1927, only three collections are in existence.

Few species of living organisms which have been studied by the professional biologist have not been seen in their native lands, and yet *Riella paulsenii* of Turkestan has been seen only once, in Denmark. At the turn of the last century, the biologist Paulsen collected a number of samples of mud from ponds in Bokhara in the hope of obtaining resting stages of crustacea. Three years later, in 1901, when the mud was cultured in an aquarium in Copenhagen, crustacea were obtained in abundance, but also a new species of *Riella*, described by Porsild. The culture became contaminated and lost, with the consequence that this organism has been seen but once, twenty-five hundred miles from its home. This species holds the record of all the *Riellas* for its aloofness.

That such an anomalous situation should be closely paralleled is almost unbelievable. Nevertheless, about the same time a quantity of mud was collected near Port Elizabeth in Cape Colony, South Africa, also for the purpose of obtaining crustacea. In 1903, six years later, a culture made in England from this mud yielded a new species of *Riella*, described as *R. capensis* by Cavers. The botanist has been more successful, however, in his onslaught on the South African species, for it has since been found in relative abundance in the temporary bodies of water called vleis on the Cape Peninsula and the Cape Flats. This appears at present to be the most abundant species of *Riella*. Mud sent from this same region by Miss Stephens to Dr. Chamberlain at Chicago for algae yielded hundreds of *R. capensis* plants thirteen years after collection.

It is quite evident, then, that *Riella* is an exceedingly rare plant, and one is

not surprised that it has been seen by few botanists. Because of its anomalous structure and perhaps because of its rareness, the literature on the genus has become rather voluminous. Its morphology has aroused the interest of such masters as Hofmeister, Montagne, Leitgeb and Goebel, whose researches were often of necessity based on few plants or even on dried herbarium specimens soaked in water. Living material, and especially viable spores, were at a premium.

It is of peculiar interest to note that among all the Bryophytes, including both liverworts and mosses, *Riella clavsonis* (now called *R. parisii*) was the first plant in which the fusion of gametic nuclei during fertilization was observed. This work of Kruch in 1890 was also the very first case among all plants in which it was observed that before the fusion of fertilization the male and female nuclei undergo such changes that their respective chromosomes are clearly visible.

A more detailed examination of the several species of *Riella* shows all of them to have the same basic form, namely, an elongated stem-like structure on one side and over the top of which extends a very thin wing, and from the base of which grow a number of rootlike hairs, the rhizoids (Fig. 2). The stem is round or oval in section, and the wing is a single cell in thickness. The latter extends over the top and side of the stem in much the same manner as an unbroken row of feathers in the headdress of an Indian might extend from his forehead over his head and down his back; to make the parallel more accurate, however, the solid ribbon of feathers should be thought of as starting under the chin and forming a wavy band over the face and head and down the back almost to the ground. The feathers under the chin are very short, and they become progressively longer over the head and shoulders, and

FIG. 2. *RIELLA AMERICANA*

AT THE LEFT, A MALE PLANT WITH THE MALE SEX ORGANS OR ANTERIDIA NEAR THE OUTER MARGIN OF THE WING; AT THE RIGHT, A FEMALE PLANT WITH THE ATTACHED NON-SEXUAL SPOPHYTES IN VARIOUS STAGES OF DEVELOPMENT; AT THE LOWER CENTER, OUTLINE OF A SINGLE ASEXUAL PLANT ENCLOSED WITHIN ITS PEAR-SHAPED INVOLUCRE. DRAWINGS BY S. FLOWERS.

again gradually shorten near the ground. It is this upright wavy wing which led Barnes to call *Riella* a ruffle standing on end; and Hofmeister considered *R. helicophylla* of Algeria, in which the wing is sometimes wound spirally around the stem like a spiral staircase, one of the most remarkable forms in the vegetable kingdom.

In some species the plants are monoecious; that is, they have both male and female organs on the same individual. In others, as in the American species, the two sexes constitute different individuals, which, in their general form, are similar. The male sex organs or antheridia, each of which develops a large number of sperms, occupy a very

unique position, since they occur in a row on the outer margin of the wing, which is here somewhat thickened; in other words, they are found near the tips of the Indian's feathers, somewhat comparable to the eyes in the feathers of a peacock. The youngest of these are found under the Indian's chin, and they are progressively older over the top and back of his head. In the female individuals, the outer edge of the wing is unthickened; the flask-shaped female organs, the archegonia, are found attached to either side of the stem near its upper extremity. Each archegonium contains an egg in its swollen basal portion.

A knowledge of the life history of

other liverworts would lead one to feel certain that the fertilized egg does not develop directly into another individual like the parents from which it had its beginning. Indeed, the zygote grows by numerous cell divisions into an altogether different kind of individual, a sporophytic or spore-bearing non-sexual plant, which in no manner resembles the gamete-bearing ruffle; its size, form, structure, and the number of chromosomes contained in its nuclei when they are dividing, are all different. Instead of being ribbon-shaped, it consists of a stalked globe. Instead of having rhizoids growing into the soil, the base of the stalk consists of absorbing tissue embedded in the stem of the ruffle-like plant. In other words, it is never a free individual, but shows parasitic tendencies, although it remains green through a part of its life span and can therefore manufacture at least a part of its own food. As it matures, it occupies a successively lower relative position on the stem of the ruffle, not by any power of shifting its position, but by the continued elongation of the stem of its gametophytic mother on which it is a partial parasite.

The globular sporophyte produces in its interior a large number of spores, which develop at the expense of a number of adjacent cells. The latter act as "nurse" cells; that is, their protoplasm and walls break down and serve as food for the developing spores. A mature spore is thick-walled and covered with numerous spines, which have been thought of as aids in the dissemination of the plant by becoming attached to aquatic animals or floating vegetation. In Texas, however, they seem also to aid in preventing too great a dissemination and consequent loss since, if they did not become attached, they might be swept down the creek and out of the canyon into dry areas where they have little chance of germinating and growing. They do not always germinate

readily, but may retain their vitality for many years.

The ultimate product of the germination of the spore is again the gamete-producing plant or ruffle. But such is the perversity of nature that few plants or animals grow immediately into a stage resembling the adult in shape and structure. Such juvenile states often give a clue to the ancestry of an organism. During its development, *Riella* passes through several distinct stages before it takes on the form of the adult.

The first stage after germination consists of a cylinder of green cells arranged end on end, with a long one-celled rhizoid growing in an opposite direction. Does this filamentous stage refer back to an algal ancestry many millions of years ago? By their fruits they may be known, but also by the juvenile forms through which they pass.

Next, the young growing plant assumes the shape of a paddle or tennis racquet one cell in thickness, which may be compared with some of the simplest thallus bodies among the other liverworts.

True to its reputation for anomalous structure, the next stage is completely unexpected. If *Riella* were to continue to grow along the tennis racquet plan, it might, indeed, produce a highly complex structure. Increase in size might be accompanied by the establishment of dorsiventrality and by the formation of air pores, complex air chambers, a midrib, a definite notched apical growing point and many other structures seen to-day in the more common liverworts. But development along any of these lines would result merely in a slight variation from the structures found in *Marchantia* and other hepaticas. Who knows but that the ancestors of *Riella* started out on such a plan of keeping up with the Joneses—or perhaps they were the Joneses with which other liverworts were trying to keep up. At any rate, these early progenitors apparently de-

eided that, to be different, development must proceed along a new line, even if some of the gains previously made must be sacrificed in the change. So they hit upon a plan, unknown anywhere else among the liverworts, of absorbing most of the broadened part of the tennis racquet and starting a new lateral growth from its base. It is this anomalous lateral sheet one cell in thickness which grows directly into the stem and wing of the adult plant.

The filamentous stage shows radial symmetry, or symmetry around a line, while the tennis racquet stage shows bilateral symmetry, or symmetry on the two sides of a plane. The adult stage has no symmetry at all, as viewed from the side; but a bilateral symmetry becomes apparent as a result of a plane cutting the stem in half and extending out through the middle of the wing, cutting this structure into two equal halves, each a half cell in thickness.

In such a complex manner is the life cycle completed. The ruffle produces the sex cells; fertilization is followed by growth into a globular spore-bearing partial parasite; and the spore develops again into the ruffle form through successive filamentous, thalloid and lateral-outgrowth stages.

Among the several species, much variation is shown in the habitat occupied. Some live near sea-level, while others are found in the mountains, up to 5,500 feet. Some occur in brackish waters and others can tolerate only fresh waters. Many of them are found only in temporary bodies of water, but the Texas form is not at all averse to living in the permanent pools of Madera Creek. They are aquatic and are normally found submerged; but they may be able to live for a time out of water, with the drying of the lakes or streams. While some of them grow readily in culture in the laboratory, others do not, and it has not yet been found possible successfully to trans-

plant *R. americana* from Madera Creek to Musquiz Creek or to its former home in Limpia Creek. Several of the species have been found among aquatic vegetation, but the Texas form prefers to grow in almost pure stands, neither mixed with other plants nor shaded by floating algae. Little is known about the reaction of these organisms to light, temperature and soil and water conditions. In some respects they seem able to adjust themselves to extremes, as is the case with the Texas species, which grows normally in the cool waters of a well-shaded canyon but was found for a time in the warm waters and the intense sunshine of a playa lake near Lubbock, Texas, and at another time under a three-inch sheet of ice. Nothing is known about the factors responsible for the very local distribution of the various species and for the disappearance of some of them.

For a plant as rare as Riella, one is surprised to find that it is, in a sense, almost world-wide in its distribution. Found in both northern and southern hemispheres, and in both eastern and western, four of the six continents are represented. And yet the genus has been found in only eleven countries, and in almost every instance, except South Africa, a given species occurs in only one or two very local areas. Not over twelve species occur in not over eleven countries.

The geological origin of the Riellas is hidden in the haze of the past. It would scarcely be expected that a soft-bodied form could leave behind a fossil record as easily as a woody trunk or a stony fruit, and definite fossil records of any liverworts are consequently rare. Nevertheless, there has been a belief among many botanists that the liverworts as a group are old geologically. During the last few years, several excellently preserved though not fruiting liverworts have been found dating as far back in geologic times as the Car-

boniferous; tissue structures were beautifully shown in these fossils. Such discoveries raise a faint hope that in the course of time even some fossil Riella-like plants may be located.

Any theory of the geological origin and distribution of a genus which lacks all representation in fossil form is, of course, purely hypothetical. It is, nevertheless, hoped that the ideas presented in this connection may serve as a point of departure in building up a hypothesis of the geological origin of Riella, even though the present state of our knowledge will permit neither their proof nor their disproof.

Starting with the concept that the liverworts have been in existence through a number of geologic ages, we find some evidence for the belief that the genus Riella itself is not a very young one, but that it has gone through a long evolutionary history. Thus, a new genus is rarely present in the northern and southern hemispheres, and in the eastern and western; it usually requires many ages for it to become disseminated into four continents. Neither would a new genus be expected to have its species adapted to a variety of habitats, for such adjustments also require time. Again, while the liverworts in general exhibit juvenile stages in their development, Riella reaches its adult condition by a much more indirect and circuitous route, in that it passes through three distinct and unlike stages before it reaches the adult form of the ruffle. It is a generally accepted principle that each of these stages represents a relic of an ancestral condition, and that the larger the number of such stages the older is the plant likely to be geologically. On such a basis, the ruffle structure is a highly derived form and in no sense primitive. And finally, a cue may be taken from the flowering plants of the Canary Islands; a very large percentage of this flora is a relic vegetation, left over from earlier geo-

logic periods. Perhaps *Riella affinis*, which is found only in the Canaries, is a similar relic. For these reasons, it seems rather logical to see in Riella an ancient plant, a landmark on which is recorded the structural history of an ancient race.

Probably history began to unfold itself for the ruffle plant in those ancient lands which are now southern Europe and northern Africa. All but three of the species are still there, not having deserted the land of their birth. Just how long ago this event occurred, it is impossible to say; probably several geologic ages before the Pleistocene ice swept in repeated waves over northern Europe and America, a certain liverwort began to show tendencies toward that anomalous development which was finally to culminate in the present ruffle plant. Conditions for the growth of this primitive organism must have been favorable and, with the passing of the ages, it became wide-spread. Since the agents of dissemination of the present species are not definitely known, the agents in the ancient world can only be postulated. Primitive birds must have migrated to an extent, and there is no reason for denying their ability to carry spores attached to the mud on their feet then, as now. Liverwort spores have been found in relative abundance on the feet of water birds. Such an active agent was aided, no doubt, by the more slovenly changes in climate, land levels and the size of land masses.

One can imagine the ancestors of Riella crossing the forerunner of the Mediterranean either by the agency of birds or by numerous short steps around the edges of the sea or across land bridges. From this Mediterranean center, the plants became distributed in all directions. Transport on the feet of birds seems the most logical explanation for their migration to the Canary Islands. Between southern Europe and Turkestan are numerous bodies of

water and many mountain streams; probable similar conditions ages ago afforded plenty of opportunity for a series of short jumps, aided by water birds. Crossing the Sahara region and the equator presents a more knotty problem, but not an insurmountable difficulty. It is well known that many European families and genera of the higher plants, the seeds of which are many times as heavy as the spores of a liverwort, have made the same jump to the region of the Cape of Good Hope; a period of more uniform climate or a series of jumps from one mountain range to the next offers a likely explanation.

The passage to America is the most difficult to explain. There is good evidence for the supposition that the bulk of the genera of plants both in Europe and America were at one time, during a period of mild climate, located in a mythical region far to the north. From this center of dispersion, identical or similar plants migrated southward into the two hemispheres, east and west. Perhaps the ancient Riellas also succeeded in extending their range into this birthland of the north from which they could migrate, along with the higher plants, into North America. At such a time the genus must have had a very wide range, covering possibly most of the northern hemisphere. Under favorable living conditions, the number of species was probably much greater than now. Then came the ice ages, driving the plants southward and eradi-

cating many of the species. Some of them, perhaps, were able to adjust themselves to a cold climate, in which connection one is reminded of the Texas plant growing for a time under an ice sheet. But most of the species became extinct as a result of the onslaught of the several periods of glaciation. If the species in the western hemisphere were ever numerous, they have been reduced to a single one.

The few species of *Riella* which are left in existence to-day are true plant orphans, left to shift for themselves in a world which is none too kindly toward them. Each has gone its separate way, having lost all track of its brothers similarly stranded in other countries. And yet one wonders whether a systematic search may not reveal a much wider distribution, so that the present gaps between the Mediterranean region and Texas, South Africa and Turkestan may not be filled with other habitats for the known species, or for species yet to be discovered.

These considerations, combined with the disappearance of some of the species for many years, lead one to the conclusion that the genus *Riella* is dying out, that it represents the last stand of a race which is finding this age too unfavorable for its existence. If this hypothesis be true, the ruffle plant is likely in another geologic age to be shelved in the antiquarian records along with *Lepidodendron*, *Sigillaria*, the dinosaur and the mastodon.

BULLETS AND SPEAR-HEADS EMBEDDED IN THE TUSKS OF ELEPHANTS

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INTRODUCTION

I HAVE long been interested in foreign bodies embedded in the tissues of fishes. Years ago I found a mummified pipefish and later the backbone of a fish each held in the mesenteric folds of a fish. These and other like data were brought together and published in 1922 with the title, "Foreign Bodies Found Embedded in the Tissues of Fishes."¹ However, long before this I had dissected 54 sting-ray stings and 4 catfish pectoral spines from the jaw muscles of a hammer-headed shark.²

And finally I recently dissected a pair of jaws of the black-tipped shark from the Gulf of Aden with like surprising results. In these jaws and the adherent muscular tissues—the jaws had merely been "roughed out" and dried—I found 13 sting-ray stings. Three of these were embedded in the gum-like tissues (technically the "thechal folds") surrounding the teeth. But most surprising was it to find a fourth spine embedded in the solid cartilage of the jaw. These spines had produced interesting abnormalities in the corresponding rows of teeth of the shark which will be described in another paper. The general account of their inclusion in the jaw tissues of this shark has been published in the May, 1932, issue of this journal.

Becoming greatly interested I worked through various general odontographies (works dealing with the tooth structures of man and the lower animals) to see

¹ *Natural History*, Vol. 22, pp. 552-557, 6 figs.

² *Science*, 1907, Vol. 25, p. 1005.

what they contained bearing on this subject of tooth abnormalities in sharks. Various interesting things were found in these books, among them several accounts of foreign bodies included in the tusks of elephants. This has led to the running down of all the available accounts, and it has seemed of interest to bring the data together into definite form.

INCLUSION OF BULLETS IN THE TUSKS OF ELEPHANTS

The tusks of the elephant are the permanent upper incisor teeth. They are not only the largest of the elephant's teeth, but in proportion to the size of the body are the largest teeth belonging to any animal. Each tusk consists of two parts; the outer solid part or tusk proper; and the root or the basal part embedded in the upper jaw. This basal part consists of a hollow chamber or pulp cavity filled with blood vessels and nerves. The walls of this chamber, formed of dentine or ivory, are thinner behind where the pulp cavity is largest. These tusks grow at the base from persistent pulps throughout the life of the elephant, their increase in length being checked only by the wear and tear of fighting and of uprooting trees.

The presence of bullets in the tusks of elephants is not very uncommon. This phenomenon has been known for hundreds of years to ivory workers who have found them in cutting up the tusks. Ivory is one of the most prized of the commodities which are luxuries. The greater part of the ivory of commerce is

obtained by shooting the elephants which bear it. The intent is to have the bullets enter the heart or the brain, and it is in these latter that we are most interested since many of them find lodgement not in the brain or head but through bad aim or movement of the animal they penetrate the tusks. This matter has been well put by Dr. George F. Kunz in his interesting book, "Ivory and the Elephant."³ Dr. Kunz has examined scores of specimens which justify the title of this section. After noting that thousands of elephants have been killed for their tusks, "which are, so to speak, the animal's jewels," he continues as follows.

"A very curious circumstance is that not uncommonly there is found buried in the tusk an iron bullet which was intended to kill the animal but which got no farther than a lodgement in the very thing the hunter aimed to possess." Then he brings forward the following general statement, based on an examination of many specimens, which will serve as an admirable introduction to this part of my article:

These specimens afford good evidence that many elephants are struck by shots but are not killed. In other words, judging from the number of tusks showing encysted iron or lead bullets, it is self-evident that these were not the bullets that ended the animal's life; of course the wounding of the tusk would at most give an elephant a powerful shock, and unless the shot that hit the tusk were closely followed by another to the brain, the animal would escape practically uninjured, and when the tusk had been traversed by the ball the direction usually indicates that it could not have inflicted a mortal wound even if its momentum were not too much lessened by the resistance of the ivory it had passed through. Instances of recent shooting showed that the ball had shattered the tusk and this had regrown, thereby proving that the bullet in question had not been that which had killed the elephant.

In presenting the data showing the

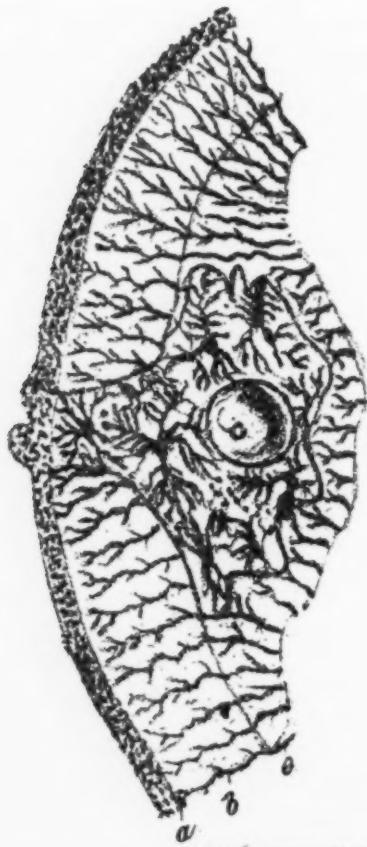
development of our knowledge of this interesting phenomenon, the chronological order will be followed. Probably a search through the old natural history books in which the elephant is referred to would reveal accounts of embedded bullets dating back into the 1600s. But the earliest account I have chanced upon dates back only to 1729.

In that year Frederic Ruysch published at Amsterdam his "Thesaurus Magnus & Regius qui est Decimus Thesaurorum Anatomicorum." On page 36 of this, he speaks of having (presumably in his museum) a section of an elephant's tusk in which was found a brass or copper ball which had penetrated it "explosione sclopeti." Fig. 8 of his plate II portrays the ball and its capsule of secondary dentine but not the tusk. This figure is the earliest representation of this phenomenon known to me, but it is too crude and insignificant to be reproduced herein. Later on, figures will be reproduced showing how such a ball penetrates the tusk, how it becomes embedded and how the orifice becomes closed.

Next Daubenton, in the first edition of Buffon's "Histoire Naturelle,"⁴ says, under the heading "Un moreau d'ivoire renfermant une balle de fusil," that in the "Cabinet d'Histoire Naturelle" there is a section of elephant's tusk containing a rusty iron ball "qui a cinq à six lignes de diamètre." Behind the ball the ivory is disturbed and compressed for about 7 lines (seven twelfths of an inch). The ball by its impact had thus formed a kind of tubercle or callus entirely foreign to the structure of the tusk. The tusk was thicker at this point than anywhere else. There was no mark anywhere of the method of entry. He was certain that this ball had been embedded in the tusk for some time. No figure is given.

³ New York, 1916, pp. 222-225.

⁴ Paris, 1754, vol. IX, pp. 161-162.



—After Goodsir, 1844

FIG. 1. A BULLET EMBEDDED IN AN ELEPHANT'S TUSK

A DIAGRAMMATIC DRAWING TO SHOW HOW THE BULLET IS COVERED OVER AND HOW THE APERTURE IS FILLED. FOR EXPLANATION OF THE LETTERS SEE THE TEXT.

The next account chanced upon is in A. G. Camper's "Description anatomique d'un éléphant mâle."⁵ Camper had seen in the collection of the Prince of Orange a triangular section of an elephant's tusk with two iron bullets included. These lay loosely side by side in a cavity without trace of entrance passage. Our author himself possessed

⁵ In Pierre Camper's "Oeuvres," Paris, 1803, Vol. II, p. 160; pl. 22, fig. 6; and pl. 27, fig. 11.

a piece of tusk with an embedded leaden ball. There was nothing to indicate how it had found entrance. These bullets had penetrated the pulp cavity and gradually had become covered over by deposited material, which, however, did not fit closely to the balls.

Camper's figures, while not the first published to show such inclusions, are the first that I have been able to find. However, neither of them is particularly interesting and as better ones will be reproduced later in this article, it does not seem necessary to reproduce them in here.

Next comes J. F. Blumenbach,⁶ who, after giving several untraceable citations about inclusions of iron balls in elephants' tusks, states that he possessed such a specimen. Much more interesting was his specimen of a tusk as large as a man's thigh containing an unflattened leaden bullet. This lay in the cavity of the tusk covered over with a sort of rind of stalactitic material. The external perforation which the bullet had made was closed as it were by a cicatrix. He gives no illustration.

Cuvier, in his "Eléphans Vivans et Fossiles,"⁷ notes that it is not at all unusual to find bullets included in the tusks of elephants without any trace of aperture by which they found entrance, and says that there was such a specimen in the Paris Museum. (This of course may have been the specimen described by Daubenton in 1754). These data are repeated in his "Ossemens Fossiles,"⁸ where he notes that there are three specimens in the Muséum d'Histoire Naturelle. Unfortunately, he also gives no figures.

Goodsir in 1844 wrote the first defi-

⁶ "Handbuch der Vergleichende Anatomie," Göttingen, 1800, p. 42.

⁷ Annales Museum d'Histoire Naturelle, 1806, Vol. 8, p. 115.

⁸ New ed, Paris, 1821, Vol. I, p. 48.

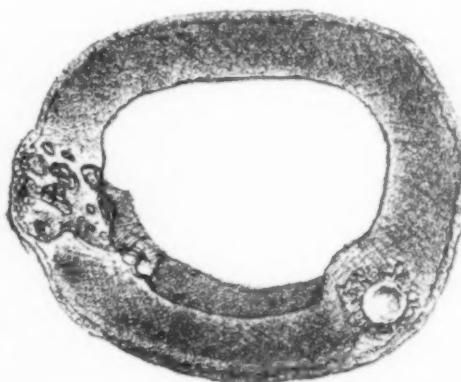
nite paper known to me "On the Mode in which Musket-Bullets and other Foreign Bodies become Enclosed in the Ivory of the Tusks of Elephants."⁹ His material came from the cutlery firm of Rodgers at Birmingham, which imported the ivory for knife and razor handles. Goodsir goes minutely and at least in part histologically into the mode of regeneration by which the aperture is closed and the ball surrounded with ivory. It is not the purpose of this article to go into these histological details; however, it would seem that a reproduction of Goodsir's general statement and of some of his figures with their somewhat detailed legends will make clear his conclusions and will illuminate the subject.

One thing detected in all his specimens was of importance as affording a clue to the method of enclosure. This is that

. . . in none of the specimens are the bullets or foreign bodies surrounded by regular ivory. They are in every instance enclosed in masses, more or less bulky, of a substance which, although abnormal in the tusk of the elephant, is nevertheless well known to the comparative anatomist, as occupying the interior of the teeth of some of the other mammals, and usually considered to be ossified pulp. It was evident that the pulp had ossified round the bullet, as the first step towards the separation of the latter from it. In one specimen the bullet has become enveloped in a hollow sphere of this substance, on the surface of which the orifices of medullary canals are situated. [Fig. 4 herein]. In other specimens the irregular ivory, which surrounds the balls, had become smooth on its surface, the medullary canals had disappeared and the regular ivory had been formed in a continuous layer over the surface of the mass. In one tusk a cicatrix was seen occupying the hole through which the ball had passed, a circumstance which, when seen in similar specimens, has greatly perplexed anatomists. It was observed, however, that, in this instance, the shot had passed through that part of the tusk which had been within the

socket; and bearing in mind that the tusk is an organ of double growth, it appeared probable that the shot had been plugged up from within by the ossified pulp, and from without by the continued growth of cement, without any regeneration of the displaced ivory; a hypothesis which was afterwards verified by examination.

Two of Goodsir's figures will here be reproduced. Fig. 1 shows a ball embedded in a tusk. Here *a* is the layer of cement; *b*, the primary or regular ivory with its so-called Retzian tubes; *c*, the ball; *d*, the irregular ivory with its system of tubes and cells; *e*, the secondary regular ivory. Fig. 2 is a cross-section of the base of a tusk showing how a bullet has passed through one wall of the tusk to become embedded in the one opposite. The orifice has become filled with irregular ivory covered on the outside with cement. Here the track of the ball has not become ossified as it has in some other cases figured on the same plate. The material, filling the orifice

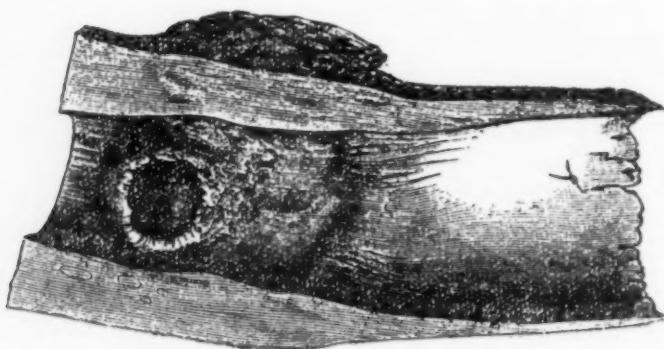


—After Goodsir, 1844

FIG. 2. ANOTHER TUSK WITH AN EMBEDDED BULLET

A SECTION OF THE BASE OF A TUSK IN WHICH THE BULLET HAS PENETRATED THE LEFT WALL, HAS CROSSED THE CAVITY AND HAS BECOME EMBEDDED IN THE RIGHT WALL. THE HOLE HAS BECOME FILLED WITH IRREGULAR IVORY COVERED WITH CEMENT EXTERNALLY. THE BALL IS EMBEDDED IN REGULAR IVORY.

⁹ *Transactions Royal Society of Edinburgh*, Vol. 15, pp. 93-100, pl.



—After Bland-Sutton, 1910

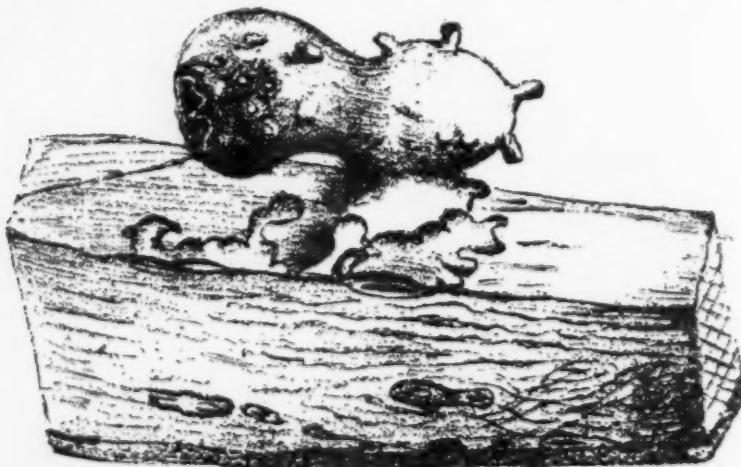
FIG. 3. BASE OF A TUSK WITH AN EMBEDDED BALL
AN IRON BALL PROJECTS INTO THE PULP CAVITY OF A TUSK WHERE IT HAS FORCED OUT OF PLACE THE IVORY LINING. ON THE OUTSIDE IS A WART-LIKE MASS OF DEPOSITED MATERIAL. SPECIMEN IN MUSEUM OF THE ROYAL COLLEGE OF SURGEONS OF GREAT BRITAIN.

and covering over the ball, has become deposited by the regenerated pulp.

J. Bland-Sutton, in an interesting article on "The Diseases of Elephants' Tusks in Relation to Billiard Balls,"¹⁰ figures two fragments of elephant's

¹⁰ *The Lancet*, London, 1910, pt. 2, pp. 1534-1537, 7 text-figs.

ivory in which iron bullets are embedded. The better of these two figures is reproduced herein as Fig. 3. Here the bullet has partly broken through the wall of the tusk into the pulp cavity, the point mushrooming the inner layers of the base of the tusk into the pulp cavity. On the outside is seen a nodule,



—After Goodsir, 1844

FIG. 4. COPPER BALL ENCLOSED IN AN IVORY SPHERE

IRREGULAR IVORY HAS BEEN DEPOSITED AROUND THE BALL WITH CANALS, SOME CLOSED BUT OTHERS OPENING INTO THE PULP CAVITY OF THE TUSK. THE MASS IS ATTACHED TO THE WALL AND IN TIME WOULD HAVE BEEN ENCLOSED IN IT.

probably of cementous material, deposited to close up the aperture. Bland-Sutton further states that such inclusions have been known to ivory turners for centuries and then concludes thus:

The thorough way in which a bullet may be embedded in the solid part of an elephant's tusk, and no mark betray it, is proved by the fact that one has been found in a billiard ball. Such a specimen is preserved in the Museum of Royal College of Surgeons of England.

Kunz (1916, p. 224), in discussing such inclusions as these, says that one of the finest collections known of such wounded ivory is to be found in the Buffalo Museum of Science. In the collection presented by Mr. C. H. Wood there are no fewer than 34 specimens which show inclusions of bullets, etc. Kunz had evidently examined these, for of the effects of the bullets on certain tusks he writes that:

When the bullets are of lead, the metal is generally scattered more or less, and has affected the ivory differently than in the case of steel bullets. It is said to poison the dentine, frequently causing large exostotic growths, exhibiting strange and abnormal bulbous or spicular forms, and hollow spaces often of large size. These tumors are designated odontoma [bone tumors]. . . . On the other hand, in several instances where steel bullets were found, the ivory was only partly decomposed or absorbed away from the bullet, leaving it loose in a hollow enclosure, thus making a kind of ivory rattle. . . . In a very peculiar instance a flattened bullet was found encysted in the hollow rim end of the tusk, where it was only three-eighths of an inch wide, but a growth an inch through had formed around the bullet.

This material in the Buffalo Museum of Science is in the hands of Dr. C. E. Cummings, who is planning an article describing these inclusions. Since this is probably the largest collection in America of such maimed ivory, Dr. Cummings' article will be awaited with great interest.

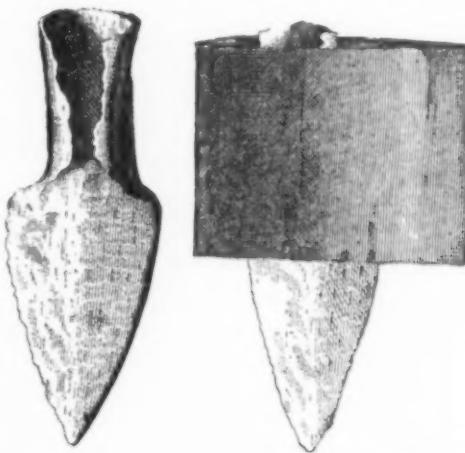
Such a growth covering a ball, as is referred to by Kunz, is shown in Fig. 3

of Goodsir's plate. Of this, which is reproduced herein as Fig. 4, Goodsir (1841) says:

A copper ball [is] enclosed in a sphere of irregular ivory, on the surface of which are the orifices of the Haversian canals. Some of the orifices have closed and present the appearance of irregular projections. The mass has begun to be attached to the regular ivory of the tusk, and would in time have been inclosed in it. The ball must either have passed across from the opposite side of the tusk, or must have sunk below the level of the hole by which it entered.

Lastly, C. S. Tomes, in his "Manual of Dental Anatomy, Human and Comparative,"¹¹ noting that bullets are sometimes found embedded in tusks, offers the following remarks:

The thin walls of the tusk near its open [hinder] end do not offer very much resistance to the entrance of a bullet; the result of such

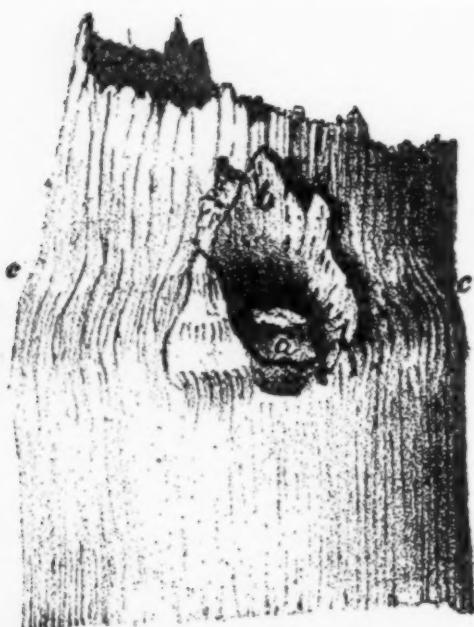


—After Combe, 1801

FIG. 5. IRON SPEAR-HEAD EMBEDDED IN A TUSK
ON THE RIGHT THE SPEAR-HEAD IS EMBEDDED IN THE IVORY. ON THE LEFT IS THE SPEAR-HEAD AFTER EXTRACTION FROM THE TUSK.

an injury is not, as might have been expected, the death of the pulp, but in some cases abscess cavities become formed in the neighborhood of the injury, while in others less disturbance is

¹¹ Seventh ed., London, 1914, p. 543.



—After Goodsir, 1844

FIG. 6. BASE OF A SPEAR-HEAD EMBEDDED IN A TUSK

THE SHAFT OF THE SPEAR HAS BROKEN OFF, AND ONLY THE BASE OF THE HEAD IS VISIBLE. THE TUSK BEYOND THE POINT OF INJURY IS SOMEWHAT DWARFED IN SIZE. FOR EXPLANATION OF LETTERING SEE TEXT OF THIS ARTICLE.

set up, the bullet becoming enclosed in a thin shell of secondary dentine, or sometimes lying loose in an irregular cavity, and round this the normal "ivory" is deposited; upon the outside of the tusk no indication of anything unusual is to be seen, so that the bullets thus enclosed are found by ivory turners only when sawing up the tusks for use.

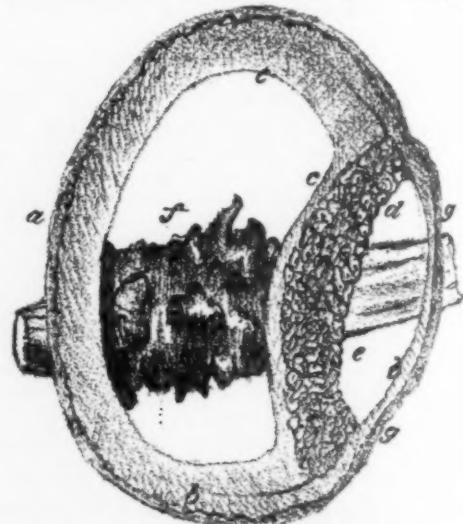
These explanations are more or less incomplete and before leaving the subject it may be well to quote Goodsir's carefully considered explanations (1841, pp. 97-98). He thinks that foreign bodies enter tusks and are preserved in three ways. Here is his first:

When the ball hits the free portion of the tusk, if it only penetrates to a certain depth of the ivory, no change whatsoever can take place. Neither the cement nor the ivory can

be reproduced. In course of time the hole may be obliterated, the ball may be got rid of by wearing down of the ivory, and the ivory under the hole may be strengthened by the formation of new substance. When the ball is detained by the ivory, but penetrates so far as to wound the pulp, the latter ossifies round it, and the ossified portion sooner or later becomes enveloped in new ivory. If the ball penetrates the pulp, the latter ossifies round it, and becomes attached to the hole in the ivory. If the tusk is growing rapidly, and the nucleus of pulp-bone does not speedily adhere to it, the ball will ultimately be situated above the hole. The ball may also pass across the pulp, and become at last enveloped, along with its bony envelope, in the ivory of the opposite wall.

Even more important is his second description and explanation, which will be set out in his own words:

In the second class of wounds, in which the ball enters the pulp-cavity through the socket and side of the tusk, the consequent changes



—After Goodsir, 1844

FIG. 7. CROSS SECTION OF TUSK WITH EMBEDDED SPEAR-HEAD

THE SPEAR-HEAD HAS PENETRATED BOTH WALLS OF THE PULP CAVITY (THE ONLY RECORDED CASE), HAS DISPLACED THE IVORY ON THE RIGHT WHERE IT ENTERED AND IN THE PULP CAVITY HAS BECOME COVERED BY A TUBE OF IRREGULAR IVORY. FOR EXPLANATION OF LETTERING SEE MY TEXT.

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seem to be the following: first, ossification of the pulp surrounding the ball, and the ultimate application of the mass to the hole in the ivory, and, as the latter is necessarily at this part of its extent very thin, the hole is closed; second, the application to the hole in the ivory, and to the surface of the ossified pulp in it, of cement formed by the internal surface of the tusk-follicle. For although the ball may have removed or at least torn the follicle opposite the hole in the ivory, yet, as the tooth advances in the socket, the ball will in time arrive at a sound portion of the latter. There is a specimen on the table which proves that the wounded portion of the follicle may perform this duty sufficiently well. In this specimen the external surface of the cement exhibits a longitudinal fissure, with smooth rounded edges, resulting from the defective formation of cement in the situation of a longitudinal rent or wound in the membrane of the follicle, through which the ball had entered the ivory. The hole in the ivory then being plugged up externally by cement, and internally by ossified pulp, the case proceeds as in the last class of wounds—the ossified portion of the pulp surrounding the ball becoming inclosed in true ivory.

His third explanation pertains to a foreign body which enters from above into the pulp cavity and hence does not wound the tusk. This class of bodies will be considered at some length in the next succeeding sections.

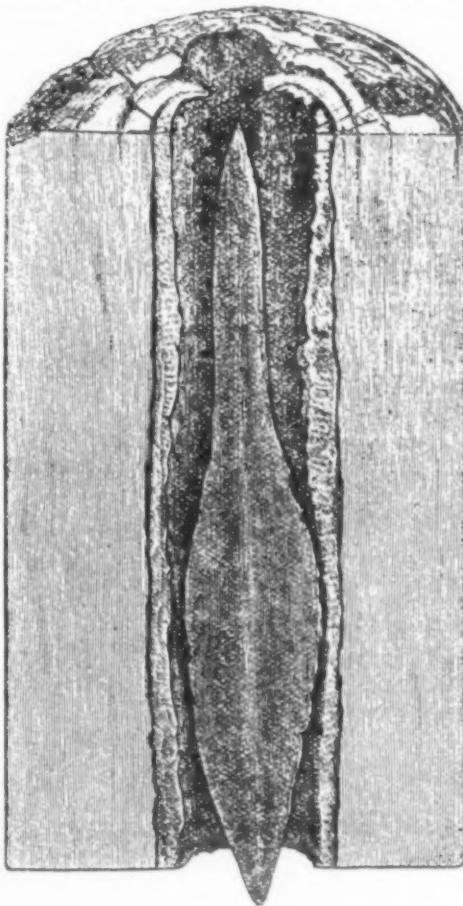
IRON SPEAR-HEADS EMBEDDED IN THE TUSKS OF ELEPHANTS

So far back as 1801, Charles Combe, of Exeter College, Oxford, gave an "Account of an Elephant's Tusk in Which the Iron Head of a Spear Was Found Imbedded."¹² This tusk was six feet long, weighed 50 pounds and was supposed to have come from Africa. The tusk on being shaken gave out a rattling noise about two feet from the base. It was cut in two in this region and in it was found a much corroded iron spear-head. Combe's figures are reproduced herein as Fig. 5, the earliest

¹² *Philosophical Transactions, Royal Society London*, Vol. 91, pp. 165-168, pl.

known figures of such inclusions in the tusks of elephants. It is also believed that Combe's account of such is the earliest ever published.

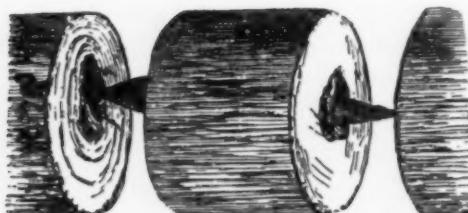
The right-hand figure shows a part of the tusk with both ends of the spear-head protruding, while the left-hand



—After Bland-Sutton, 1910

FIG. 8. LONGITUDINAL SECTION OF ELEPHANT'S TUSK WITH EMBEDDED SPEAR-HEAD

HERE IS AN IRON SPEAR-HEAD, $7\frac{1}{2}$ INCHES LONG BY $1\frac{1}{2}$ INCHES WIDE, EMBEDDED IN A SHEATH OF SECONDARY DENTINE. THERE WAS NOTHING ON THE EXTERIOR OF THE TUSK TO INDICATE ITS PRESENCE. SPECIMEN IN MUSEUM OF THE ROYAL COLLEGE OF SURGEONS OF ENGLAND.



—After Tomes, 1914

FIG. 9. CROSS SECTIONS OF ELEPHANT'S TUSK SHOWING EMBEDDED SPEAR-HEAD

THIS IRON WAS FIRMLY HELD IN THE INTERIOR OF A TUSK, WITHOUT EXTERNAL TRACE OF ITS PRESENCE.

figure shows the much corroded spear-head as it was when extracted from the cavity in which it lay loosely. The presumed manner in which it became embedded will be explained later.

John Goodsir, in an extensive communication on bullets found in the tusks of elephants (which has been considered at some length earlier in this paper), in 1844 figured in his plate a tusk across the base of which he had found an iron spear-head embedded. He does not refer to this in his text but does make things clear in the extensive legends to the figures. In Fig. 6 herein, Goodsir's Fig. 6 is reproduced. Here the reader will see the broken-off base of the shaft (*a*) of the spear. An irregular mass of material (*b*), which Goodsir states is cement, has formed around about the orifice of the wound. Had the shaft broken off deeper in, this cement would have closed the orifice with a cicatrix. This wound has stunted the growth of the tusk which is smaller and weaker beyond the wound, as may be seen at *c-c*.

Fig. 7 is a reproduction of Goodsir's drawing of the tusk in cross-section through the pulp cavity at the base of the tusk. Here the spear-head is separated from the pulp cavity by the deposition of "irregular ivory" (*f*) around

it in the form of a tube or sort of Siamese-twin ligature. Here is Goodsir's explanation of figure and phenomenon: *a* is cement; *b-b*, irregular ivory deposited after the tusk was wounded; *c-c*, regular ivory deposited subsequent to the wound; *d*, irregular ivory enclosing a vacant space; *e*, an abscess or sinus continuous with the pulp cavity; *f*, a mass of irregular ivory forming a tube around the foreign body; *g-g*, irregular ivory which has bent outward in drying.

It may be noted just here that this is the only spear-head recorded (in the literature known to me) as being found in any other than a longitudinal position—*i.e.*, one running lengthwise with the axis of the tusk.

The next account of such matters has been found in the article by Bland-Sutton previously referred to (1910). He figures a longitudinal section of an elephant's tusk containing an iron-spear head $7\frac{1}{2}$ inches long by $1\frac{1}{2}$ inches wide. His illustration is reproduced herein as Fig. 8. The specimen is to be found in the Museum of the Royal College of Surgeons in London.¹³

The next account of an embedded spear-head is found in the work by Tomes on dental anatomy previously cited (1914, p. 544, fig.). In the seventh and last available edition of this work, it is stated that this specimen was deposited by its owner, a Mr. Bennett, in the Museum of the Royal College of Surgeons. Tomes's figure of this is reproduced herein as Fig. 9. Here the spear-head has become immovably fixed in the interior of the tusk, there being nothing on the exterior to indicate its existence within. Tomes then quotes a

¹³ Neither this nor any other of the specimens noted herein as being in the Hunterian section of this museum was described in Lowndes' "Catalogue" of the collections of this museum published in 1893. They must have been presented later than that date.

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Mr. Erxleben that he know of another such specimen.

In a similar work by J. H. Mummery, entitled "The Microscopic and General Anatomy of the Teeth Human and Comparative,"¹⁴ there is an illustration (Fig. 10 herein) made from a photograph showing such a spear-head inclusion. This seems to be a new specimen never before figured or described. Of it Mummery writes:

The head of the javelin and a portion of the iron shaft are embedded solidly in the ivory. This specimen was obtained from the ivory worker by a merchant in the City, who could not be persuaded to part with it but lent it to the author to be photographed. There are two somewhat similar specimens in the Hunterian Museum of the Royal College of Surgeons.

Dr. G. F. Kunz, in his interesting book (1915) previously referred, states (p. 224) that Mr. Charles H. Wood had presented to the Buffalo Museum of Science a number of tusks with embedded spear-heads—probably the largest collection of such tusks in America. As stated above, Dr. C. E. Cummings is planning a thoroughgoing report on these inclusions.

HOW BULLETS AND SPEAR-HEADS COME TO BE FOUND FAR FORWARD IN THE SOLID IVORY

The facts as to these inclusions have been set forth. The manner in which

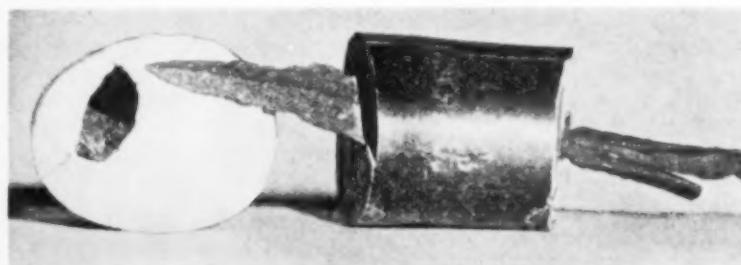
¹⁴ 2nd. ed., London, 1924, p. 231, text-fig.

the bullets become embedded is of course clear, but not so the inclusion of the spear-heads, save in one case (Good-sir's). It is now in order to explain this and to show how all are frequently found much farther forward than they were when first introduced. Some hints have been dropped as to this for the bullets, but the whole matter will now be made entirely clear.

The explanation was fairly well set out by one of the first describers of the phenomenon of inclusion. Combe (1801) writes thus

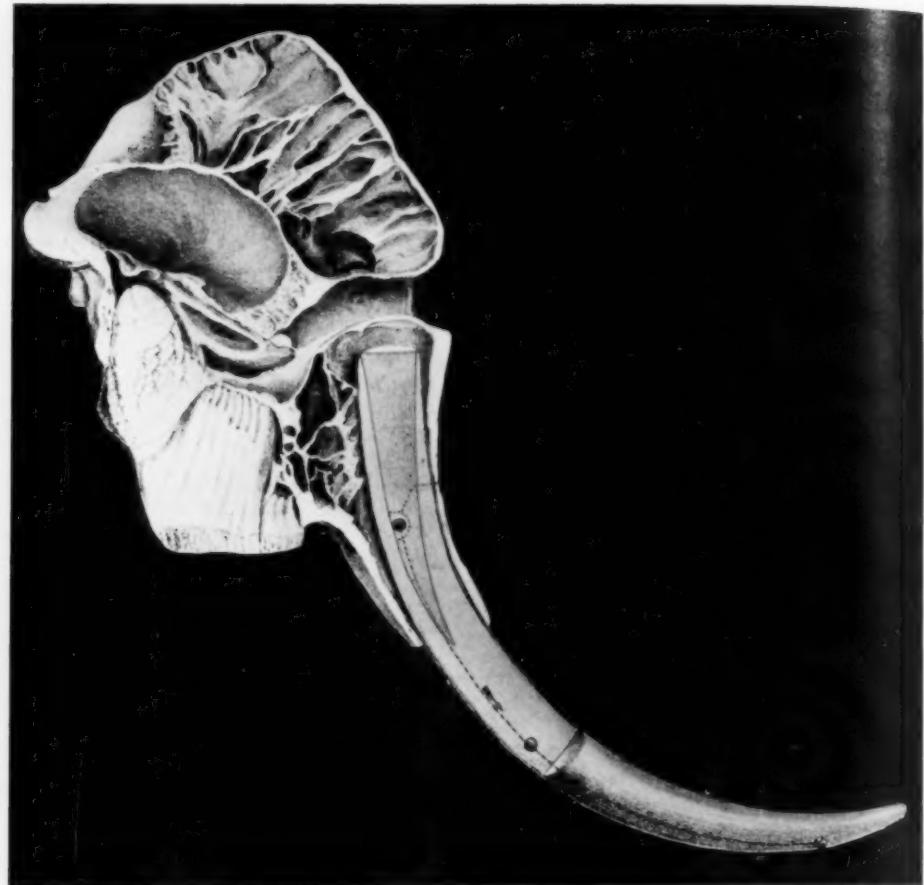
The most probable conjecture is that the spear entered at the basis of the trunk. If we examine the skull of an elephant, it will be found that the tusks are strongly articulated in the upper maxillary bones. In the males, they reach as high as the thin plate, which separates them from the nasal cavity, whence the tusk arises. We have then only to suppose that the spear struck, somewhat perpendicularly, between the interior angle of the eye and the proboscis; the interposing plate of bone would yield without much difficulty; and the cavity of the tusk is placed immediately beneath.

The presence of an extraneous body in the substance which fills the conical cavity of the trunk, would be the cause of inflammation and subsequent suppuration. In the meantime, the spear-head acting by gravity would descend, till prevented by the resistance of the converging parietes of the cavity. After a process of time, when the tusk had been protruded further from the skull, in consequence of growth, fresh bony matter [ivory] would necessarily be de-



—After Mummery, 1924

FIG. 10. ANOTHER SPEAR-HEAD EMBEDDED IN A TUSK
HERE NOT MERELY THE SPEAR-HEAD BUT ALSO ITS IRON SHANK WAS HELD IN THE IVORY WITHOUT
EXTERNAL TRACE OF THE PRESENCE OF EITHER.



—After Owen, 1845

FIG. 11. LONGITUDINAL SECTION THROUGH SKULL AND TUSK OF AN ELEPHANT

THIS SHOWS HOW THE TUSK, WITH ITS PULP CAVITY, IS SET IN THE BONES OF THE FRONT OF THE SKULL. ABOVE ITS BASE IS THE NASAL CAVITY, AND ABOVE THIS THE CANCELLOUS BONE OF THE HEAD HONEYCOMBED BY MANY SINUSES. THIS SHOWS HOW A SPEAR-HEAD DROPPED VERTICALLY MIGHT EASILY PENETRATE THE SKULL AND COME TO REST IN THE PULP CAVITY. THE DOTTED LINE IN THE TUSK SHOWS HOW A BALL MIGHT PENETRATE THE PULP CAVITY, WHERE EMBEDDED IT MIGHT BE CARRIED FORWARD UNTIL, EXPOSED BY THE WEAR OF THE TUSK IN UPROOTING TREES, IT MIGHT BE BROUGHT TO THE SURFACE.

posed to preserve a corresponding relation between the size of the cavity and the tusk; and thus the spear-head would gradually become imbedded within the ivory.

The explanation is perfectly sound, but the mode of entrance of the spear-

head into the pulp cavity of the tusk will not be wholly clear to the reader who is not acquainted with the osteological make-up of the head of the elephant. What is needed is an illustration showing this, and this is supplied by Richard

Owen.¹⁵ In his "Text" Owen makes no reference to either bullets or spear-heads inclosed in the ivory of elephants' tusks, in fact, he does not seem to have known of the latter, since he makes no reference even to Combe's paper. However, in his "Atlas" he figures an elephant's head and tusk in section to show how the tusk is implanted and to make clear its relation to the other bones of the head. His drawing is reproduced herein as my Fig. 11.

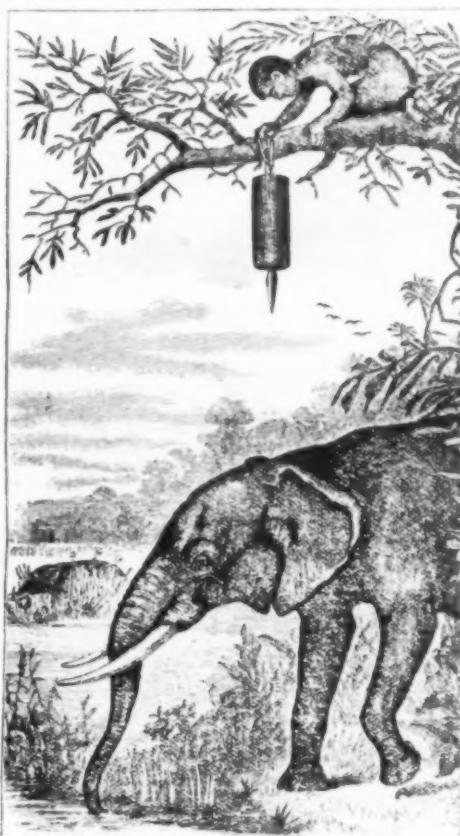
In his long explanatory legend for this figure he effectually makes clear the structure of the head, the penetration of the bullet and how it is progressively carried outward toward the tip of the tusk. Here is his explanation:

Vertical section of the skull of the Indian Elephant, with the molars and incisive tusk of one side, the latter showing its alveolus and pulp-cavity exposed by a longitudinal section. The dotted line through the fore-part of the pulp-cavity shows where a ball might penetrate that cavity and lodge at the opposite side, being there surrounded by osteodentine, then encased in ivory; and by progressive growth of the tusk be afterwards carried in the direction of the arrow into the middle of the solid exerted part of the tusk. The continuation of the dotted line shows how the ball, if it had penetrated the base of the tusk of a young Elephant, might ultimately be discharged.

Still the question is unanswered as to how the spear-head reaches the elephant and gets into the pulp-cavity at the base of the tusk. This is supplied by Tomes (1914, p. 543-544) as follows for the specimen in the Museum of the Royal College of Surgeons:

It is to be presumed that a trap was set with a heavily loaded spear, or that it was dropped [by hand] from a tree, with the intention of entering the brain of the animal as it was going to water, both of these methods of killing elephants being practiced in Africa. Sometimes as many as 100 natives are posted in trees and armed with loaded spears, the elephants

¹⁵ "Odontography; Atlas," 1845, pl. 146, fig. I.



—After Bland-Sutton, 1910

FIG. 12. AN AFRICAN ELEPHANT TRAP

A SKETCH TO SHOW HOW THE AFRICAN NATIVES KILL AN ELEPHANT AS IT VISITS A DRINKING PLACE. THE HEAVILY LOADED SPEAR IS DROPPED ON THE ANIMAL'S NECK OR SHOULDER WHERE IT INFlicts A TERRIBLE WOUND. SOMETIMES THE SPEAR PENETRATES THE SKULL JUST ABOVE THE BASE OF THE TUSK. WHEN THE WOODEN BEAM IS BROKEN OFF, THE SPEAR-HEAD SOMETIMES DESCends INTO THE PULP CAVITY OF THE TUSK.

being driven under the trees by others. But in this case [of the specimen in the Museum of the Royal College of Surgeons] the spear penetrated [easily through the forehead, made of delicate cancellous bone much separated by the multiple large sinuses, and, the handle being broken off, it made its way into] the open base of the growing tusk, which looks almost vertically upwards [see Owen's figure], and then

the iron part appears to have broken off [from the loaded handle]. This did not destroy the pulp, but the tooth continued to grow, and the iron part, measuring no less than $7\frac{1}{2}$ by $1\frac{1}{2}$ inches, became so completely enclosed that there was nothing upon the exterior of the tusk to indicate its presence.

This particular spear-head referred to, it should be noted just here, is the one refigured from Bland-Sutton (1910) as



—Photograph by Herbert Lang

FIG. 13. AN ELEPHANT TRAP IN THE FOREST SOUTH OF MEDJE, BELGIAN CONGO

NOTE THE GREAT LENGTH AND HENCE GREAT WEIGHT OF THE LOG TO WHICH THE SPEAR IS AFFIXED. FROM THIS ONE CAN JUDGE OF THE TERRIBLE BLOW AND WOUND INFILCTED WHEN IT FALLS. THE TWO LIANAS HANGING DOWN ON EITHER SIDE ARE CONNECTED WITH A TRIGGER WHICH THE PASSING ELEPHANT TRIPS, CAUSING THE SPEAR TO STRIKE IT.

Fig. 8 herein, and also that referred to in other paragraphs.

Mummery makes essentially the same statement as Tomes, but neither he nor Tomes gives a figure showing this curious, native method of hunting. This lack, has, however, been supplied by Bland-Sutton (1910), whose illustration is reproduced here as Fig. 12.

That this is not a fanciful sketch may be found by consulting almost any book of adventure and hunting in west central Africa, more narrowly in the Congo. Thus Reginald D. Cooper, in his "Hunting and Hunted in the Belgian Congo,"¹⁶ says of the native ways of capturing elephants that:

One of these is to use a long, broad-bladed spear, the wider part of which, or that part near the shaft, is generally barbed; two feet behind this a large mass of clay encased in grass or strips of bark-like bandages is affixed round the shaft, sometimes the clay is replaced by a section of hardwood tree of great weight. The whole thing, with shaft and blade, measures some seven or eight feet in length. To use this the wily natives climb up a tree that overhangs the path taken by the elephants when going down to the river or pool of water, and as the game passes under the tree the weapon is driven down into the neck, and with the heavy weight behind it the blade often penetrates to a great depth. The elephant in trying to free itself of its burden, rubs against the tree trunks and branches; this only makes matters worse for the poor brute, for the blade is being dragged to and fro, inflicting an awful wound. Eventually the beast drops from loss of blood and is speared to death.

Sometimes, however, the drop-log instead of being discharged, so to speak, by a native, is tripped by the elephant itself. This mechanism is thus described by another traveler in the Congo, Cuthbert Christy, in his "Big Game and Pygmies."¹⁷

The drop-log with its spear pointing downwards is raised vertically to a height of eighteen or twenty feet above an elephant path,

¹⁶ London, 914, p. 183.

¹⁷ London, 1924, pp. 83-84.

usually at a spot where it passes between two trees standing close on either side of it. The path is carefully chosen, generally one which the elephants must use to reach a plantation or group of gardens. The log is held in position by a thick forest-made creeper rope passed over a convenient branch, or a cross-bar placed for the purpose. At the end of the rope is a wooden peg which is ingeniously adjusted close to the ground between two stakes driven into the earth, or between two saplings, on one or the other side of the track. Stretched tightly across the path is a trigger-rope, one end of which is attached to the peg which keeps the whole contrivance in position, and upon the fine adjustment of which depends success. Any animal tripping over the trigger rope unhitches the peg and instantly releases the log and spear. The trap is kept unset with the log in position. On some suitable night when the elephants are raiding the crops the natives go and fix the trigger-rope, taking away at the same time some safety-catch on the peg. When the herd retires to the forest at dawn there is pretty sure to be a casualty.

Neither of the authors just quoted nor any of the other books consulted give an illustration of such an elephant trap, but I am fortunate in being able to supply this deficiency. Such a drop-log with its spear and two lianas acting as a release is admirably portrayed in a photograph made by Herbert Lang, leader of the American Museum's Congo Expedition 1906-1915. This photograph (Fig. 13) shows this effective apparatus as set up by the natives in the forest south of Medje, Congo Belge.

The tremendous blows struck by these heavily weighted spears can be realized in the following (unverified) quotation by Bland-Sutton from Stanley.—“On the road before leaving the bush, we passed a place where an elephant spear had fallen to the ground, and buried itself so deep that three men were unable to heave it up. Such a force, we argued, would have slain an elephant on the instant.” This was found April 8th, 1888, on his second journey from Fort Bodo to the Albert Nyanza, shortly after reaching the Ituri River.

If such a spear penetrated the elephant’s skull above the open base of the tusk, as shown in Fig. 11 from Owen, and if in the animal’s struggles the beam were broken off as described above, the spear-head by gravity would descend into the open pulp cavity. Thence by growth processes it would be covered in ivory and carried forward into the body of the tusk, as is portrayed in Figs 8, 9 and 10.

The exact method by which the spear-head is transferred forward into the solid part of the tooth is admirably put by Mummery (1924, p. 231) as follows:

The persistent growth of the great incisor teeth forming the tusks of the Elephant sometimes gives rise to remarkable conditions. Several cases have been recorded where an Elephant has been struck by a javelin or loaded spear which has penetrated the pulp at the free-growing end, and the vitality of the tissues has been so great that the death of the pulp has not followed, but the spear [head], carried forward by the growing tooth, has been completely surrounded by the subsequently deposited ivory and has become immovably fixed in the tusk. Such a case is shown in the photograph, figure 142 [Fig. 10 herein]. The head of the javelin and a portion of the iron shaft are embedded solidly in the ivory.

It has been stated by both Bland-Sutton and Tomes that sometimes natives, stationed in trees over elephant paths, drop by hand loaded spears into the heads or backs of elephants in the hope of bringing about their deaths. This is confirmed by the ethnologist Vanden Plas in his work “Les Kuku.”¹⁸ The Kukus of the Anglo-Egyptian possessions (northeastern Congo) climb trees as noted above and by hand hurl down on the passing elephants spears much larger and heavier than those normally used in hunting.

The heads of these spears will measure 14 inches long by 2 inches wide and have

¹⁸ In C. van Overbergh, “Collections de Monographies Ethnographiques,” Bruxelles, 1910, VI, p. 164.



FIG. 14. A SPEAR FROM THE CONGO
FROM THE COLLECTIONS OF THE AMERICAN
MUSEUM CONGO EXPEDITION, 1906-1915.

a base or haft inserted 5 inches into the bamboo shaft. These shafts are as much as 5 feet, 3 inches long. The extremity (lower?) of the shaft is wrapped in elephant hide firmly bound with lianas. This mass of skin is $15\frac{3}{4}$ inches long and 7 inches in circumference (over both hide and wood). This is presumably to add weight to the spear and to make it fall straight.

Two elephant spears similar to these were brought back from another part of the Congo by the Lang-Chapin expedition elsewhere referred to, and are now in the collections of the American Museum. I have examined these, which have long blades and heavy handles 3 $\frac{1}{2}$ or 4 feet long, and curiously enough that part of the shaft to which the spear-head is attached has been wrapped in some sort of material and this covered over with antelope (?) skin.

One of these spears is portrayed in Fig. 14. The head of this spear is $14\frac{1}{2}$ inches long and 2 wide near the base. The handle is $42\frac{1}{2}$ inches long. The enlarged and weighted lower end measures $7\frac{1}{2}$ inches long by $3\frac{1}{4}$ wide. The outer covering of hide is without seam and seems to have been pulled on like a stocking. Under this is another leather covering. The grip end of the wooden shaft is covered with grass and mud and the whole closely wrapped with some liana-like material, presumably to give weight and a firmer hold for the hands. Attached is a leathern sheath to cover and protect the blade. This comes from Faradje, Belgian Congo. Dr. James H. Chapin has examined this spear and identified it as an elephant spear intended to be dropped by hand from a tree.

That these accounts are correct may be seen in Fig. 15, a native Congo pictograph from an elephant's tusk brought back by Herbert Lang, leader of the American Museum Congo Expedition of



—From Lang, 1918.

FIG. 15. PICTOGRAPH FROM CONGO IVORY

SHOWING HOW ELEPHANTS COME TO GRIEF FOR PLUNDERING NATIVE PLANTATIONS.—THE ELEPHANTS, FRIGHTENED BY TWO MEN BEATING DRUMS, ARE SPEARED AS THEY PASS BENEATH THE TREE. AN INFURIATED ELEPHANT CHARGES ONE OF THE MEN, WHILE THE LITTLE DOG (WHOSE WHEREABOUTS IS INDICATED BY A CLAPPER FASTENED TO HIS COLLAR) STANDS READY TO TRACK THE SCENT OF ANY ELEPHANT WHICH ESCAPES.

1909-1915, and reproduced by him in 1919 in an article "Famous Ivory Treasures of a [Mangbetu] Negro King."¹⁹ Here this method of spearing

¹⁹ *Natural History*, vol. 18, p. 548.

elephants by an entirely different Congo tribe is most interestingly portrayed. It will be readily recognized that such a spear would be very effective for killing an elephant. Both figure and legend are copied from Lang.

HUMAN POSTURES AND THE BEGINNINGS OF SEATING FURNITURE

By Dr. WALTER HOUGH

U. S. NATIONAL MUSEUM

IN the long history of man before the periods marking important advances in his arts, there is as yet little known of his manners. Any conjecture as to his postures at times of rest must depend largely upon observations on men unconscious of civilization. Fortunately, there have survived groups of races, such as the Australians, pocketed off the main current, whose habits may be a tentative index to those of men of the archeological periods.

At the same time there run parallel with these data other data that grew out of physical conformations of the body after the assumption of an upright posture, that is, postures which have become functional and assumed eventually the order of instincts. The latter are only noticed here, and it is not intended to enter into the consideration of postures that have been adopted during an increased artificiality of life in various environments. These postures may be referred to housing conditions of primitive social life, on flat areas of eave floors or domiciles, to rest positions on the hunt, march or camp; or to positions required at work. These are a direct response to man's physical needs, due to his acquired sitting posture. We consider that man's natural position of rest is squatting, sitting, kneeling or lying down. A winded athlete or any one with faulty respiration assumes a bent posture and later a sitting position, but not an erect posture.

Three type postures can be recognized: squatting, which would be indicated on bad ground in any climate, practiced generally by men as a rest position,

coupled with ease of going into action and also a convenient pose for certain classes of work. The second type is sitting, with legs at sides, or vertical, or extended more or less, or crossed under or crossing each other. The latter is generally woman's posture, and is indicated in warm climates on prepared, smoothed camp or floor areas under safe conditions. The third posture is kneeling, generally transitional or required in certain arts. It is sometimes a poised or mixed posture with one knee up. It evidences a reduction of height for utility and the application and control of applied force in various work, and is practiced by both men and women.

With these postures will be indicated a fixity of custom for a long period in which an artificial seat is non-existent, man keeping close to the ground or sitting on a ledge, stone, tree or other suitable article. The employment of definite artificial aids satisfying the natural need did not reveal itself until social organization became more complex.

The generality of free-moving animals maintain an alert posture under all conditions, this being broadly a necessity to survival in the "tooth and claw" organization of nature. Protective structures and tremendous proliferation relegate some animals to a low-habit grade, seen in the majority of forms below the vertebrates, except insects and in some other classes of life where external encasement substitutes for the skeleton.

It is not remarkable, then, that in the early stages of man there survives the



SEAT OF THE SUN GOD. MESOPOTAMIA. BRITISH MUSEUM.



ANCIENT GREEK THRONE CHAIR. BERLIN MUSEUM.

alert posture habits or instincts, and that these have become softened in the artificial organization of society which secures periods of ease under protection.

Of the appliances with which man ministers to his comfort we may mention especially his sleeping and seating furniture. Before these, even the essential fire steps into the background. It is not saying that to be housed a man requires fire; attention is merely called to the accommodation of the house to man's physical frame at rest and not to the matters of heating and cooking.

The house itself is not here considered, whether the act of sheltering artificially is an unconscious reaction to exterior

influences that nature projects or even the consideration of the question whether the geometries of the house represent mere physical anthropological dimensions. The within of a house is undoubtedly calculated in its various three-dimensional extensions to contain a limited number of human beings where essential movements and postures are also limited. Observations show that living in a house at certain phases of culture, say of the Bronze Age, differed greatly from that of later times.

Pointing out the greatest difference, we present the fact that in early times the house was only a portion of outdoors, home life and open-air life being in an unequal ratio. The house, as an

adjunct of outdoor life, was a shelter enclosing against storms and observation, for the rest periods and private affairs of family existence. Human social organization that necessitated a house for a family or a communal house had progressed far toward aggregation of habitations called hamlets, villages, towns, cities and metropoles. The house, considered as a part of outdoor life, continued into higher phases of social order and even still in the highest examples preserves some of the primitive customs.

As to the essential furniture of the early habitation, an estimate of this may be made and checked up against the furnishings of houses of the uncivilized who still remain close to the ground. At once it will be seen that rest is the prime motive. The bed or such assemblages equivalent for the purpose of interposing buffers against the hardness of the ground appears in its rudiments. The development of the bed has many inconsistencies and adaptations to climate and other regulative factors.

This primitive resting device of a "bed" has had an important bearing on the development of seating furniture, perhaps in a primary sense. There are innumerable observations of the sec-

ondary use of bed devices as a seat. It is even necessary to promulgate a tabu against the urge of highly civilized man to destroy the contours of a bed by sitting ungracefully on it.

In a low state of culture described, man early learned to interpose some medium between his body and the ground, in the form of "bedding" for use at night. Materials used would be furs, grass, leaves, softened fibers of bark and suitable plants in masses, suggested still by the long line of antecedents of beds and cushions that in some areas, as in the East, solve the general problem of furniture.

In the more advanced history of house construction and planning it is found that, especially in temperate and northern environments, banquettes often form part of the structure. In such environments generally houses were partly subterranean, to put into effect the acquired knowledge that this feature was advantageous in shielding the family to some extent against both heat and cold as well as the winds, and making the dwelling more stable and safe. Upon the banquette the family sat, worked, lounged and slept. The bodily heat of



SIMPLE BACK REST SEAT. CONGO, AFRICA.



STONE SEAT WITH ARMS. MANABI, ECUADOR.



ONE-LEG STOOL. CONGO, AFRICA.

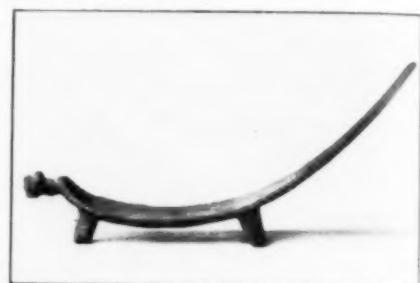
the occupants and the central fire, if maintained, would raise the temperature of the air of the house, and the banquette served also to elevate the sleepers from the cold floor into the zone of warmer air. That this first knowledge of heated air was put to practical use is unquestionable, as Eskimo examples of the high banquette show. The bank saved the sleeper also from rodents and thus served as a protection.

The banquette is the forerunner of benches and beds as house furniture, not universally, but in some environments and particular advances in culture peculiar to these environments. The line is clear, say in England, but would not apply to the ancient customs descending in the East in the use of cushions and mats which conserve the state of affairs in the time when man kept close to the ground.



CARVED WOOD SEAT. ANGOLA, AFRICA.

The Oriental habit of reclining on cushions may be traced presumably to the necessities of a pastoral life, which involve the constant moving from place to place with the herds and in general an existence in the open air, cutting down house furnishings to a low figure. This, it is presumed, was the inheritance of some nations if not all who do not possess rigid seating furniture. The vast hordes that swarmed from Asia toward the Mediterranean or warmer waters of the East were of the recumbent type. The pastoral peoples of the Near East were also of this class. The Mahomedan conquests of the seventh century spread the custom far and wide, in most cases superseding cultures like



CURVED SEAT. TURKS ISLAND, W. I.

that of Egypt and Mesopotamia which had advanced to the stage of resting furniture. The Romans, breaking with Egyptian and Greek customs, adopted in the height of their luxury the so-called effete reclining postures of the East.

The earliest seats were thrones of gods and kings, examples of which have been uncovered by explorations in Mesopotamia. Among the oldest is a chair depicted in mosaic, recovered by Dr. Wooley from Ur of the Chaldees. Many examples are shown in Greek and Roman ceramics and sculpture.¹

¹ Hough, "Ancient Seating Furniture in the Collections of the United States National Museum," Smithsonian Report, 1930, pp. 511-518 (publication 3101), Washington, 1931.

THE STORY OF THE ISOLATION OF CRYSTALLINE PEPSIN AND TRYPSIN

By Dr. JOHN H. NORTHROP

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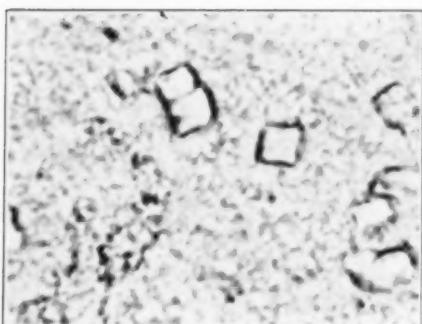
One of the most striking peculiarities of living things is the rapidity and precision with which the chemical changes necessary for their existence are carried on. The process of digestion is a familiar example. Proteins are split in the stomach into much smaller compounds, and this process is continued in the small intestines. The final products are precisely those needed for the nutrition of the animal and are formed from proteins with little or no evolution of heat or expenditure of energy. The process can not be duplicated in the laboratory, since chemical hydrolysis of proteins yields different products and in any case can be accomplished only by violent treatment and the expenditure of considerable energy. Similar examples of the efficiency of the reactions which take place in the animal could be multiplied indefinitely. It is now known that these specific accelerating effects which living cells exert on the reactions occurring within them and in their vicinity are due to the presence of minute amounts of some substances formed by the living cell and which have come to be known as enzymes. Without them life could not exist and yet they themselves are not living.

For centuries this property of living matter was regarded as a process of vital activity entirely outside the realm of experimental science. Evidence gradually accumulated, however, to show that the living cell was not necessary for some, at least, of these characteristic reactions; and one case after another was found in which the reaction could be made to take place without the living cell. But it was not until Buch-

nner in 1897 discovered that fermentation of sugar could be caused by yeast extract containing no living cells that it was generally admitted that the enzyme was essential rather than the cell itself.

It had been suspected long before Buchner that the process of gastric digestion was due to the presence of some characteristic substance, and Schwann, in 1836, definitely assumed the existence of such a substance and gave it the name of "pepsin." The existence of trypsin had also been suspected early in the nineteenth century, but was not definitely assumed to exist until the time of Corvisart and of Kühne, who gave it its present name. A large number of other enzymes were then discovered by means of their characteristic reactions. It was assumed that since these reactions occurred an enzyme must exist to cause them, but there was no direct proof of the actual existence of enzymes, and, in fact, their existence as ordinary chemical compounds has been frequently questioned. The problem was analogous to that of the causative agent of an infectious disease. This agent is assumed to exist because the disease occurs, but the assumption can not be proved until the etiological factor is actually isolated.

In the meantime the chemists had found that many purely chemical reactions were accelerated by the presence of small amounts of substances which apparently took no actual part in the reaction, and Berzelius pointed out that the properties of these substances were strikingly similar to those of the active agents found in living cells. He named the general phenomenon catalysis and

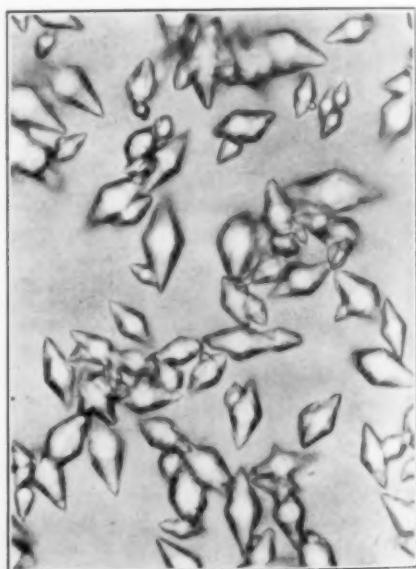
CRYSTALLINE TRYPSIN ($\times 910$)

considered enzymes as a special case of catalysis.

The name "enzyme" was proposed by Kühne for these organic catalysts. In the last 50 years enzymes and enzyme reactions have been studied intensively by chemists and physiologists. The chemists have been interested primarily in the mechanism of the reaction and the physiologists in the nature of the reactions, and both chemists and physiologists have spent a great deal of time trying to isolate the enzymes themselves. Rapid progress was made in the study of the nature of the reactions caused by enzymes, but the mechanism by which they caused these reactions to take place and the nature of the enzymes themselves remained quite unknown.

Before discussing what enzymes are, it is well to review what they do. Pepsin and trypsin are typical enzymes, and the reactions which they accelerate are good examples of enzyme reactions in general. Both pepsin and trypsin cause proteins to decompose into smaller molecules but do not carry this process as far as the amino acids which are the ultimate building stones of the proteins. Along with these chemical changes there are marked changes in the physical properties of the protein. If the protein is originally insoluble it is dissolved rapidly by the enzyme, and if it is already soluble the viscosity of the solution decreases very markedly. It has

often been assumed that, especially in the case of pepsin, these physical changes were not accompanied by any chemical change, but the apparent change in physical properties without accompanying chemical change is simply due, in the writer's opinion, to the fact that the chemical changes are very slight and hard to measure. According to the current theory of catalytic reactions in general, all the reactions which are observed to take place in the presence of pepsin and trypsin are already occurring, although at an extremely slow rate, and the characteristic effects of the enzymes are due to the fact that certain of the very large number of spontaneous reactions are greatly accelerated, while others are not. This peculiar property of accelerating certain reactions and not others is referred to as the specificity of the enzyme and is frequently considered another of their peculiar characteristics. In reality, however, all chemical reactions are specific and enzyme reactions do not differ qualitatively in this respect from any other chemical reaction. The time rate

CRYSTALLINE PEPSIN ($\times 1,000$)

at which these reactions occur and the effect of varying the quantity of protein or the quantity of enzyme also differ more or less from the results obtained from simpler chemical reactions, but again the difference is quantitative rather than qualitative and the anomalous results can usually be shown to be due to some complicated side reaction.

Another peculiarity of the action of these enzymes is the fact that pepsin digestion occurs much more rapidly in acid solution than in alkaline solution, while trypsin digestion occurs much more rapidly in alkaline solution than in acid solution. Proteins, when dissolved in acid, are present in the form of acid salts, and when dissolved in alkali are present in the form of alkali salts, and it is probable that trypsin acts only on the alkali salts of the proteins, while pepsin acts only on the acid salts. That this is the explanation rather than some effect of the acid or alkali on the enzymes themselves is indicated by the fact that the optimum concentration of acid for pepsin digestion is different with different proteins. The same thing is true for the optimum concentration of alkali for trypsin digestion. There is, apparently, a third class of proteolytic enzymes, like papain, which react more rapidly with the neutral protein molecule (Willstätter). Trypsin differs from pepsin in another respect in that it attacks denatured proteins, i.e., proteins which have been heated, very much more rapidly than the native protein. Both enzymes possess the striking property of destroying dead cells rapidly but are not injurious to living cells. The puzzling fact that the stomach and small intestine, although composed largely of protein, are not digested, even though very rapid digestion takes place in the solution with which they are in contact, is an example of this peculiarity. A partial explanation of this difference be-

tween living and dead cells was found to be due to the fact that neither pepsin nor trypsin can enter living cells, whereas they are very rapidly absorbed by dead tissue. If living fish or worms or frogs or bacteria are placed in strong solutions of either pepsin or trypsin, nothing whatever occurs. The organisms are uninjured and live indefinitely. Any dead tissue may be dissolved, but the living cells are not injured. In the meantime none of the enzyme is taken up by the tissue of the animal, since the amount of enzyme in the solution remains perfectly constant.

If dead animal tissues are placed in the same solution, they are very rapidly digested. Before digestion occurs, measurement of the amount of enzyme in the surrounding solution shows that the enzyme is rapidly taken up by the dead tissue and disappears from the surrounding solution. When the tissue has been digested or dissolved, the enzyme is liberated again. This fact, of course, simply removes one puzzle and substitutes another, since it is now necessary to know why the enzyme should penetrate dead tissue but not living tissue. This puzzle, however, has the advantage of being a very general one and not at all restricted to enzymes, since, in general, living cells are permeable only to very few substances, while dead cells are easily permeable to almost any substance in solution.

There remains, also, the difficulty of explaining why the enzymes do not digest the surface of the cells, even though they can not enter. There is good reason to believe that the surface film of cells is not protein, and its behavior in fact is much more similar to that of an oil, so that this oil-like film is probably the mechanism which prevents living cells from being digested. When the cell dies this film is destroyed and the enzyme enters and digests the protein.

INHIBITION OF TRYPSIN AND PEPSIN DIGESTION

It was mentioned, in discussing the peculiarities of pepsin digestion, that the course of the reaction was not what would be expected from ordinary chemical theory. It has been found that the quantity of protein digested per minute decreases rapidly as the reaction proceeds. This peculiarity is caused by the inhibitory effect of products formed during digestion on the activity of the enzyme. It may be strikingly demonstrated by adding increasing quantities of these products to the protein solution before the addition of the enzyme. The more digestion products are added the slower the digestion; and in the presence of a large amount of digestion products practically no digestion occurs. The enzyme-protein system in some respects closely resembles the toxin-animal system, since the enzyme causes the formation of substances which protect the protein from the effect of the enzyme, just as the injection of toxin into an animal results in the production of antitoxin, which in turn protects the animal from the toxin. The enzyme inhibitor, however, is not nearly so powerful as some antitoxins nor is it protein.

CHEMICAL NATURE OF PEPSIN AND TRYPSIN

While the behavior of enzymes has been systematically worked out in the last 40 or 50 years, very little advance has been made in the knowledge of their chemical nature so that it has frequently been assumed that they represent an unknown class of compounds. Indirect evidence has been obtained, however, that some, at any rate, are proteins. The rate at which they are destroyed by heat, for instance, is characteristic for the effect of temperature on proteins. The fact that they are adsorbed on finely divided particles is also a property of proteins more than of

many other classes of compounds. Pepsin, in particular, seems to have protein-like characteristics, and in fact Pekelharing isolated an amorphous protein from gastric juice which was highly active and which he considered to be pepsin itself. He was unable, however, to show that the material was a pure substance, and the view that this protein was really the enzyme was never accepted. The writer has repeated Pekelharing's experiments several times in the last 15 years, but until recently had never been able to carry the purification any further. In the meantime Summer reported the isolation of a crystalline protein from beans which appears to be the enzyme urease.

Nearly all attempts to isolate enzymes have been done with relatively small quantities of material and in rather dilute solution. Absorption methods have also been extensively used. If enzymes really are proteins, these are not favorable conditions for their isolation, since proteins are extremely unstable in dilute solution and are easily injured by adsorption on surfaces. The attempt to isolate pepsin was again undertaken three years ago from the point of view of protein chemistry, using only those conditions under which proteins are relatively stable, *i.e.*, concentrated solutions and low temperature. The method was based originally on that of Pekelharing. The last step in Pekelharing's preparation consisted in dialyzing a protein fraction from gastric juice against dilute acid. Under these conditions a white precipitate is formed which is a protein and which contains most of the activity. This protein sometimes appears in a somewhat granular form and under the microscope looks as though it might be trying to crystallize. Many attempts were made to crystallize the protein without success. It was noticed finally that this precipitate dissolved if the suspension were warmed to 37° C. and reappeared again upon

cooling. These are good conditions for the formation of crystals, and the experiment was repeated under varying conditions and especially with more concentrated solutions, since crystallization in general occurs more readily from concentrated than from dilute solutions. A more concentrated suspension than usual was warmed to 37° C., and this solution was allowed to cool slowly to room temperature in a beaker. The next morning it was found to contain several grams of beautifully formed crystals in the form of double, six-sided pyramids. They were tested for activity and found to be highly active and also to be protein.

The activity is about 5 times that of the most highly active commercial preparation and the quantity of protein which can be transformed by the enzyme is quite extraordinary. An ounce of the crystalline pepsin under favorable conditions would digest about 1½ tons of boiled egg in 2 hours, or would clot about 600,000 gallons of milk, while it would liquefy about 10,000 gallons of gelatin in the same time. To imitate these reactions by chemical means would require a great deal of work and violent methods, but the enzyme accomplishes it without any heat effects and, what is still more remarkable, without anything happening to itself. So far as can be determined it is present after it has done its work just as it was when the reaction was started.

Only small amounts of the crystalline material could be obtained by this method, but it was found possible to modify it and eventually to dispense with the dialysis which is the most troublesome part of the method. The crystalline protein can now be prepared from commercial pepsin preparations simply by fractionation with magnesium sulphate and then with the proper concentration of sulphuric acid. The protein crystallizes very readily, in fact much more readily than most proteins

and it is easily possible to prepare half a pound in 2 days. A method was, therefore, at hand by which large quantities of crystalline protein having powerful proteolytic activity could be prepared.

The next question was whether or not this digestive power was really a property of the protein or whether it was due to the presence of more highly active molecules accompanying the protein. This question can be answered in two ways. If it can be shown that the material is a pure substance or, in other words, that it contains only one molecular species, then it follows that the protein-like properties and digestive properties must both be attributes of the same molecule. Unfortunately, it is not possible to furnish definite, positive proof of the purity of any substance. It can only be stated that so far it has been impossible to separate it into two or more substances, and this statement may be made with respect to pepsin. The composition, optical activity and digestive activity remain constant throughout 7 successive crystallizations, and this would usually be considered satisfactory proof of the purity of a substance.

As a result of these experiments it can be said that no indication was found that the material was a mixture by the usual tests. Owing to the fact that it is a protein, however, it is quite possible that the crystals are a solid solution of several related proteins. The relation between protein and activity may, however, be tested in another way by comparing the loss in activity with the destruction of the protein. If the activity were due to some other molecule associated with the protein it seems probable that conditions could be found which would decompose or change the protein molecule without affecting the activity, or *vice versa*, whereas if the activity were a property of the protein molecule itself it would be expected that anything which affected the protein

molecule would also affect the activity. It was found that this protein was denatured, that is to say, changed into an insoluble form, in very dilute alkali. This is quite unusual for a protein. A careful study of this reaction was made, therefore, and it was found that the loss in activity was just proportional to the amount of soluble protein transformed into insoluble protein when various amounts of alkali were added.

If a solution of pepsin is allowed to stand in dilute acid at 30° C. to 50° C. the protein hydrolyzes slowly so that the quantity of protein in the solution becomes less and less. Under these conditions it was found again that the decrease in activity was just proportional to the decrease in the quantity of protein present. Finally, it was found that the denatured protein formed by the action of alkali could be changed back, at least to a small extent, to the soluble form by allowing it to stand for some time after the alkali solution had been partially neutralized. The soluble protein recovered in this way has the same activity as the original protein. These experiments, therefore, show that when the protein is denatured the activity is lost and when the protein is hydrolyzed the activity is also lost, and, furthermore, that none of the products originating from the hydrolysis of the protein have any appreciable activity. They are very good evidence that the activity is really a property of the protein molecule.

There seems reason to believe, then, that pepsin (and probably urease) are proteins; but evidently, since there are many hundreds of enzymes, it can not be concluded at once that all enzymes are proteins. There is some reason to believe that trypsin is also a protein, since it has been known since the time of Kühne to be associated with the protein fraction. In fact, it had been supposed by some workers to be a nuclear protein, but Levene was able to show that this was not the case.

An attempt was made to continue the methods used by the earlier workers and to isolate a crystalline protein from pancreatic extracts. The problem turned out to be a difficult one, and a great deal of work was done before any encouraging results in the way of either a crystalline product or a product of constant activity was obtained. The most hopeful method seemed to be a combination of fractionation with acid and salt, as was done in the case of pepsin, but with trypsin it was necessary to use ammonium sulphate. A protein fraction was eventually obtained which had a constant activity and gave some indication of crystallization. The work was made difficult by the very unstable nature of the protein. This unfortunate property made it impossible to allow a solution to stand for more than a few hours, so that the usual process of crystallization, which consists in allowing a solution to concentrate or cool very slowly, could not be used. After a large number of unsuccessful attempts, Dr. Kunitz was able to secure definite, regular crystals by the very cautious addition of strong ammonium sulphate to rather concentrated solutions of the protein. The crystals are rather small and are of the cubic system. The proof that this material is a pure substance is still more difficult than in the case of pepsin, since it is more unstable. A large number of solubility experiments were carried out, but the results were not entirely satisfactory, as it was found impossible to complete the experiments quickly enough to avoid partial decomposition and corresponding loss in activity. The final solutions, therefore, always contained more or less inactive material formed during the progress of the experiments themselves. Several series of solubility measurements were carried out, nevertheless, as rapidly as possible and at 6° C. They were disappointing in that they indicated clearly that the prepara-

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tion was a mixture. To confirm this result a study was made of the changes in activity when the protein is denatured, as was done with pepsin, except that in this case denaturation was carried out by heating in dilute acid. The trypsin protein when treated in this way becomes denatured and insoluble. This experiment showed clearly that the preparation, although crystalline, was undoubtedly still a mixture, since a considerable amount of the protein could be coagulated and removed from solution without decreasing the activity of the solution. As the heating was continued, however, and more and more insoluble protein was formed, it was found that the activity began to decrease about in proportion to the formation of insoluble protein. It appeared, therefore, that the original preparation contained two proteins, one of which was easily coagulated by dilute acid and carried no activity with it, while the other one was much more resistant to acid and was associated, at least, with the activity. These results furnished also a further method of purification since, by heating the crystalline material in dilute acid, about one third of the protein could be removed without loss in activity. Considerable amounts of the preparation were treated in dilute acid in this way and a second preparation obtained which was about twice as active as the first one. It crystallizes more readily than the first preparation and the crystals are similar. The purity of this material was again tested by solubility measurements and the results were more satisfactory than with the first preparation but still not really convincing, owing again to the very unstable nature of the substance. The loss in activity when a solution of this substance was heated in acid was just proportional to the amount of native protein changed to denatured.

The protein is rapidly digested by pepsin and several careful experiments

were done in which the amount of trypsin protein digested by pepsin was compared with the loss in activity. They showed very clearly that digestion of the protein with pepsin resulted in the loss of a corresponding percentage of the activity, so that whenever a molecule of the protein is digested by pepsin it loses its tryptic power. There is, then, no evidence that the products resulting from the action of pepsin on trypsin have any tryptic power. The experiments were varied by allowing the preparation to digest itself in dilute alkaline solution. Under these conditions also the decrease in the protein concentration is exactly parallel to the decrease in the activity of the solution.

It was found by Mellanby and Wolley that trypsin solutions possessed the remarkable property of retaining their activity after being heated nearly to boiling for a short time in dilute acid. The solutions of crystalline trypsin may also be heated for a short time nearly to boiling without any loss in activity and, what is still more remarkable, without the formation of any denatured protein. This result is obtained only if a solution is allowed to cool before being tested for either denatured protein or activity. If the solution is tested while still hot, it is found that the protein is all denatured and, in addition, that the solution is inactive. It is possible to show, therefore, that the formation of denatured protein is accompanied by a loss in activity and, what is more significant, that the reformation of soluble, native protein from the denatured protein is accompanied by recovery of the corresponding activity. As in the case of pepsin, therefore, it is found that whenever anything is done to the protein molecule the activity is lost and that, on the other hand, when the denatured, inactive protein is changed back into soluble, native protein the activity is regained. If it be assumed that the activity is due to some special

active molecule, then it must be assumed in addition that the conditions for inactivating these hypothetical molecules must be the same for denaturing the protein molecule and also that the conditions for rendering the hypothetical molecule active again are precisely the same as those for forming native protein from the denatured protein. The behavior of proteins in general is so peculiar and characteristic that it is extremely unlikely that any other type of molecule would be affected in the same way and to the same extent so that the possibility that the activity is due to a non-protein molecular species present appears very remote. It is possible, on the other hand, that the preparation is a mixture or solid solution of several closely related proteins and that only one of these is active.

The general properties of pepsin and trypsin which have been determined by these experiments show that they are similar in many respects to hemoglobin. Their peculiar ability to digest proteins is lost as soon as any change, such as denaturation, is made in the molecule. The denaturation of hemoglobin like-

wise results in complete loss of its characteristic property of combining reversibly with oxygen. On the other hand, some of the properties of hemoglobin, such as its combination with carbon monoxide and its characteristic absorption spectrum, are retained by the denatured form and even to some extent by pieces of the molecule when it is hydrolyzed. In the case of pepsin and trypsin there is, at present, no indication that any of the pieces of the molecule retain their digestive power; but it is quite possible that more careful search would show more or less activity associated with one of the decomposition products. The peculiar properties of hemoglobin are known to be due to the presence in the molecule of a characteristic group which differentiates it from other proteins. (It is quite possible that the enzyme proteins likewise contain a characteristic group, but so far no evidence has been found for its existence.) They are, however, quite different from other known proteins in many respects and this difference must be due to some characteristic difference in chemical structure.

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"TRIAL AND ERROR"

By Dr. W. L. SEVERINGHAUS
ASSOCIATE PROFESSOR OF PHYSICS, COLUMBIA UNIVERSITY

A CAREFUL reading of the history of science shows that its real progress was subsequent to the introduction of unprejudiced experimentation. In this method, when at its best, the experimental results were obtained and appraised with an open mind. From these results basic explanations were sought and resulting hypotheses and theories proposed. Further observations disclosed that the first theories were either imperfect or entirely wrong. There often arose several theories which were in themselves contradictory, that theory being used which seemed best fitted to the particular problem in hand, while the others were, for the moment, forgotten. So it has gone on through the centuries, never arriving at the complete understanding of the real nature of things. This is the apparently discouraging process in the life work of the scientist. After long years of such a program one is tempted to exclaim "What price knowledge!"

In a public address in New York, I one time heard John Galsworthy say that the solution of every problem raised a new problem more difficult than the first. He cited as one example the "plumbing problem." It was a long and difficult job to learn how to bring to a large city plenty of fresh water and how to dispose of the sewage. But the problem was finally solved, and the result was that apartment houses and buildings 50 stories high were made possible. As a consequence, a huge population was cared for in a very limited area, which in turn resulted in a transportation problem for the subways more baffling than that of the plumbing.

A student just entering upon a rather prolonged sequence of studies in physics

once stopped me after the lecture and said: "I am disappointed. I have been taking courses in the social sciences and have grown weary of having one man's guess as good as another's. I had hoped that physics had arrived at answers that were final, and then early in the sequence you confess, with not too great embarrassment, that the answers to many proposed questions are not known and that the physicists are even divided in their opinions." That is a real disappointment and it is to such disappointed minds that these few remarks are to be primarily addressed. For those who have never experienced that distress this discussion may have little interest.

Carved over the portal of one of America's greatest biological and geological laboratories, great not in cubic feet but in scientific achievement, is the age-old admonition and promise, "Speak to the earth and it shall teach you." At first that sounds very hopeful, but soon the shrinking questions arise: "Isn't Mother Earth rather large for me to speak to? And anyhow where is her ear? And what language does she understand?" One grows skeptical and says: "Earth can't teach one anything. One must sit with one's thoughts and figure things out by cold logic." It is my purpose to demonstrate that while Mother Earth may sometimes leave one cold, such unaided logic leaves one colder if one is interested in the world of events. Let us admit at the start that although by neither method may one hope to arrive at the final whole truth, yet one may ascertain which of the two is more fruitful in its by-products.

It would appear obvious that the ac-

quisition of knowledge presupposes a certain amount of interest in the world and its problems. Given the required curiosity, nature itself furnishes the laboratory and equipment for endless observation, and the discovery of a new phenomenon will always result in a peculiar kind of joy. The phenomenon may not be new to the world and yet the independent observation of it is gratifying.

Allow me to give a few very simple illustrations from my own experience. I was looking at a common variety of coleus plant on our window sill and suddenly observed that the stalks of this plant were of square cross-section, with the edges quite sharp. That seemed very remarkable and wholly inexplicable. Not that I understand why they should be round, but I certainly could not understand why they should be square. Not long afterward I was sitting by the side of a botanist at the dinner table and decided to inform him of this discovery, hastening to ask whether there were many such plants. I confess that some of the thrill of the discovery left me when he told me there were perhaps a thousand or more, and that all members of the mint family had that peculiarity. I then asked him how such growth could take place. Were the individual cells perhaps square-cornered crystals? He replied, "Now you are raising a real question about which there is much discussion."

One of my greatest pleasures out on Cape Cod consists in throwing out bread crumbs to the birds and watching their table manners. They are mostly sparrows, old and young, with the young ones continually begging their parents for bread, even after they are able to fly with ease to the ground and back to the trees again. But the parents seem to enjoy it as much as the babies, so long as there is plenty of available bread. There are always a few babies so well

fed that they grow and grow until they are several times the size of their nurses. In fact, they turn out to be not sparrows at all but cowbirds. Resorting to the bird book, I find that one of the uninspiring habits of the mother cowbird is to lay her eggs in the sparrow's nest and let the unsuspecting sparrow hatch and rear the young. The conclusion is that while the sparrow may or may not be dumb, it is certainly the friend of foundlings.

One more illustration will suffice to show the gracious way Mother Earth has of teaching, if one will only speak to her. We were lying on the seashore trying to get sunburned and casually scratching around in the sand, when one member of the party cried out with considerable animation, "Oh, look at this!" It was a little greenish pod as large as one of the beans in a lima bean pod. Inside there were ten tiny but perfect replicas of shells commonly found on the shore, about the size of the folded fist. We took it along to Woods Hole and interviewed a biologist. His remarks were something like this: "That is a very nice sample and I should be pleased to take it into the class. They have not had much luck finding them this summer. It is a snail or gastropod and its name is *Busycon Caniculatum*, sometimes called 'sea whelk.' Those little shells are perhaps a month old. There are usually ten to twelve in a single pod and fifty to seventy such pods in a string. Each little shell has an animal in it. Starting as an egg it becomes a larva, which develops a shell gland and that forms a shell around the snail." I leave it to you to imagine how many conversations with Mother Earth were enjoyed before those six sentences could be placed in the book of knowledge.

These illustrations suffice to show the ease and simplicity with which one may commune with nature, but it would be misleading to leave the impression that

the serious business of modern science consists in letting Mother Earth lull us to sleep with bedtime stories.

Let us take as a more elaborate example the search for the answer to the question, "What is light?" Please note in the first place that a goal has been set and that the scratching in the sand is no longer aimless. The history of this quest shows that the thousands of years before Al Hazen and Roger Bacon may be passed over as worthless. They may have been interesting to those delighting in pure speculation for its own sake, but they got nowhere with the question itself, and the by-products of the contemplation were indeterminate. Real progress began when men began to make concrete observations on the behavior of light. Then it was found:

That ordinary sunlight could be broken up into beams of different colors in passing through a prism and that these beams could be recombined to form the original light;

That light travels more slowly through ponderable matter than through free space and that the bending of a beam of light upon entering a piece of glass is definitely related to the velocities of the light in air and in glass;

That light travels in free space with a velocity of 186,000 miles per second;

That a beam of light can be broken into two beams upon entering a clear calcite crystal and that a piece of this crystal can be so cut that one of these beams is shut off completely, while the other passes through apparently unobstructed;

That the solar spectrum is shot through with very definitely placed black lines and that these lines coincide with the bright lines from certain luminous gases;

That two beams of the same colored light can be so combined as to form darkness;

That light experiences certain influences in passing through a magnetic

field and that it seems to gravitate toward the sun in passing it on its journey from a distant star to the earth;

That some substances when charged with negative electricity lose their charge when illuminated by the proper light. Nearly all these experiments have since been repeated with radio waves.

The discovery of these facts extends over a period of three hundred years and will be forever associated with such illustrious names as Newton, Huygens, Roemer, Young, Fraunhofer, Faraday, Foucault, Maxwell and Hertz. Newton and Huygens were contemporaries, both were great experimenters and both were great philosophers and logicians. Newton concluded from his observations that light consisted of discrete particles, while Huygens concluded that it was a form of wave motion. The opinion of most scientists of the day was that Newton was right because Newton said so and he was always right. Who were they that they should dispute the great Newton?

A century later Thomas Young performed his famous experiments on interference of two beams of light, and the tide of opinion was forced to swing around and admit that Huygens was right after all. It was an unhealthy scientific state of mind to be so willing to say that things must be so because Newton said they were. They forgot that knowledge must come from the earth and not from Newton. However, little by little, the time came when all were firmly convinced that Huygens was right—light was not corpuscular but undulatory. The experiments could not be otherwise explained. Again the scientists became intellectually crystallized and this time in a wave mold. Every evidence from conversations with Mother Earth about light was stoutly resisted when it seemed to imply that a continuous wave-stream theory could not fit the observed facts.

During the past twenty-five years

there has been an increasing number of observations in the field of radiation that require introducing into the theory some of the characteristics of the old corpuscular or discrete particle concept, while other phases of the experiments require the undulatory or wave theory. The result is that physicists are now trying to accommodate themselves to the notion of light being broken up into discrete packages, where the packages are filled with waves. The undulatory theory has not been abandoned, but it has been greatly modified and extended until now it is believed that even the electrons and atoms themselves are undulations, although they are at the same time corpuscles. At any rate, experiments performed with the deflection of electrons and atoms by crystals yield results identical in form with those of light and x-rays. At last, you say, after three hundred years we have arrived at *The answer*, spelled with a capital T. Not so! We dare not hope that we have gotten *The answer*; we have only gotten *an answer*. We don't know enough about light to give the ultimate answer and probably never shall, for the evidence to date seems not to promise that we shall reduce the universe to a simple formula. The more experimenters work at the job the more complexities are revealed.

Perhaps you feel the picture altogether too dismal, and so it is if you have your heart set on the "ultimate." It appears that the final answer is not within our grasp, but that ours is the privilege to keep on speaking to the earth and to continue to learn both simple and complex truths. While mysticism and certain types of philosophy may discuss and hope to find the "ultimate," natural science seems to have concluded that such a goal is impossible in the world of events. A wider understanding of this basic principle would do much to remove a certain false

idolatry of science in the minds of the general public to-day. There appears to be a general willingness on the part of the layman to believe that whatever modern science says is not only so but is final. Such a feeling is, to say the least, highly unscientific.

What are some of the by-products of this long and partially successful series of researches for the answer to the question, "What is light?" It would take an encyclopedia to record them. The recital of a few must suffice: we have probed into the very heart of the stars, we have felt their pulse and taken their temperature; we have probed microscopic bacteria; we have learned to generate, transmit and receive radio waves; we have seen the arrival of the talking moving pictures in color; we have achieved the transmission of pictures over the wires as well as through the air. We, like Newton, can not claim to know the full answer, but we know a great deal more than he did and have reaped the harvest that he could never even have dreamed.

The process has been a long succession of carefully planned experiments with attempts to interpret results which were sometimes as expected and sometimes quite surprising. Many times the interpretation was false, as proven by further experimental results, and the latest explanation none too lucid. But in spite of the errors the trials have resulted in enormous advances in our appreciation of nature and in our control of the forces for comfort and happiness.

Professor Ogden Rood, in an inaugural address at Troy University in 1859, told the following story which illustrates beautifully the necessity for continual experimentation in the field of science in spite of what appears to be reasonably well-established theories. About the beginning of the last century there arose a great interest in the theory of optics and the development

of optical instruments. The microscope was still rather crude, but by 1840 the English opticians had increased very considerably the available light from the object under observation by increasing the angle of aperture to 135 degrees. Their leading optician, Mr. Ross, announced that it was optically impossible to increase the angle beyond 135 degrees and that therefore no further important improvements could be looked for on the microscope. In the year 1846, Dr. Gillman, of New York, who was in possession of one of the finest French microscopes produced up to that time, was told that a back-woodsman from Canastota, a little up-state village, was anxious to examine this instrument. Dr. Gillman consented, and the man came down to see it. He looked through it, twisted it, screwed it up and down until Dr. Gillman feared his sacred microscope would be ruined, but the stranger turned around and calmly said: "I can make a better microscope than that!" "Really, sir," said the doctor in contempt, "if you can make a better instrument than the first optician of France, you ought to begin at once, for you certainly will make your fortune." The doctor repeated this story to his friends with great relish, until one morning about six months later he received a very superior instrument from Canastota. This gentleman had not only produced lens combinations far superior to any known up to that time but had also increased the angle of aperture from 135 to 178 degrees. The English opticians were all upset and much controversy followed. Ross, however, had the candor to say he was not ashamed that he had been beaten, though he was mortified that he had been surpassed by a man destitute alike of scientific friends and capital. This man was Charles A. Spencer, who founded the famous lens company which now bears his name, located in Buffalo, N. Y.

If, then, this procedure is to be accepted as the key that unlocks the doors to knowledge in the realm of natural science, is it unreasonable to hope that it will yield equally surprising returns in the realm of the social sciences and religion?

Plymouth, Massachusetts, will always remain one of the most fascinating spots in the world, the real birthplace of our American Republic. That handful of stern Puritans was prompted to make the daring experiment of establishing on this remote and hostile shore a democracy where they could enjoy their civic and religious freedom. They found the carrying out of the experiment filled with bitter and unexpected sorrows. How different were the results from the anticipations that first winter when they saw their little band withering away! One can see them sitting before their fireplaces after a day of struggle, contrasting the world of reality with the world of their dreams. But they were brave and continued the experiment with its concomitant errors. The errors that developed, such as witchcraft, were so many and so grave that short-sighted present-day critics would seek to discount the whole of their endeavors. But how do you think the dreams of Elder Brewster and Miles Standish compare with the reality of to-day? They could not possibly have grasped the far-reaching results in religion and government that have flowed from that experiment so magnificently conceived and so courageously carried on.

As one roams along those little winding paths on that first old Burial Hill in Plymouth at the head of Leyden Street, the thoughts and emotions are very mixed. Those stones tell the story of great disappointment as well as of supreme joy in the launching of the profound undertaking. At the gateway to that celebrated hill stand two churches, one the "First Trinitarian

Congregational Church" and the other the "First Unitarian Congregational Church." They stand there because a difference of opinion arose which seemed too fundamental to allow organic union between the groups. It is difficult to see just how to apply the experimental method to the solution of such questions. Perhaps the experiment is one that must be prolonged over the centuries of Christian theology in order to observe the fruits of the two points of view. Such experiments in theology, as also in government, are extremely difficult because of the great number of uncontrollable variables that enter into the observations, and they require an enormous amount of patience. But unless experimental evidence pro and con can be collected, such questions must be assigned either to the realm of pure logic or to the realm of "taste."

In making this plea for the experimental method I am not unconscious of the many instances where men have spoken to the earth with great earnestness, open-mindedness, intelligence and patience and have gone away feeling that the lesson learned was far from what had been hoped for and almost too vague to be stated. Such results are known in research laboratories as "negative." They may be of great importance at times either in closing off blind alleys for other investigators or in suggesting new avenues of approach. They are, in general, however, very disappointing to the one who launches the experiment.

The now classic illustration of the so-called "negative result" in the field of light was performed in 1886 on the Western Reserve campus and is known the world over as the Michelson-Morley-Miller experiment. This famous experiment was designed and carried out to demonstrate and measure the absolute velocity of our earth in space. The sensitivity of the apparatus seemed ade-

quate to detect and measure the effect as called for on Newtonian principles, but the observations, even if they were not unquestionably negative, as Professor Miller believes they were not, were nevertheless not conclusively positive and not at all of the presupposed magnitude. These results lay unexplained for twenty years or more before they became the basis for one of the fundamental postulates in Einstein's theory of relativity.

Passing again to the field of government for an illustration of "negative results," allow me to present a part of a recent article in the *New York Evening Post*, written by William Lyon Phelps on Nathan Hale. After telling briefly the story of Hale's graduation from Yale, his teaching school, entering the army, coming with his regiment to New York, attempting to get much needed information for Washington by entering the British ranks as a spy, being caught and hanged at the age of twenty-one, Phelps concludes as follows:

Whenever I think of Nathan Hale I think of a line in the poetry of Browning: "No work begun shall ever pause for death." The paradox that success may come out of failure has never been more impressively illustrated than in the life of Nathan Hale. In his supreme undertaking he completely failed. When he was led out to execution I do not think he mourned chiefly the fact that he had to die in the flower of his youth; or that he had to leave the girl to whom he was engaged. His most poignant suffering must have come from the thought that he was a failure. In the bitterness of his heart he asked himself: "What will Washington say? He will say he wished he had sent a better man, a man who might have succeeded." But in spite of his complete failure, in spite of the fact that he never dreamed of his fame surviving his ignominious death, he died bravely, with an incomparably fine farewell.

Now suppose Hale had succeeded; suppose he had brought back information that might have given Washington a great victory; suppose this had shortened the war; suppose Hale had become a major general; and that after the war he had become President of the United States and lived to enjoy honorable old age.

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All of these successes could not begin to have to-day the inspiring effect on humanity that flows from Nathan Hale the failure.

It has not been my purpose to raise questions that are crying for solution, much less to suggest any answers to these questions, but to have laid emphasis once more on the importance of first an intelligent and alert dissatisfaction (not mere cynicism), with the *status quo*; secondly, a willingness to apply

the laboratory method of solution; thirdly, a readiness to weigh and accept the results of experimentation with an open mind letting such results be the pointing hand towards further experimentation. Unless we are willing and eager to adopt such a program in science, government, education and religion, we are not only doomed to decadence but to death. We must approach with confidence new problems in social relations and character building.

WHAT CONSOLATION IN THE NEW PHYSICS?

By Professor FREDERICK S. BREED

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A PARTICULAR outburst of Thomas Carlyle has often been extolled. When he growled, "Gad, she'd better," in vigorous comment on Margaret Fuller's famous statement, "I accept the universe," he must have aroused a thrill of kinship in the heart of many a resignationist who leans back on the everlasting arms, puts his faith in the absolute, trusts the cosmos, or simply says with Mr. Mencken, "It's a great show, look and laugh."

Few can be so entertainingly and exclusively esthetic as the irrepressible Mr. Mencken. Our western civilizations today are irretrievably moralistic. They are erected on the theory of the betterment of mankind, the improvement of human relations; on the sorely harassed theory of social uplift, if you will. Even as, in these modern days, humanism denies the supernal sanctions of orthodox religion and substitutes therefor the sanctions of mundane experience, the moral problem shows no sign of abatement or a lapsing life. Religion that short-cuts the solutions of life's puzzles through superstition tends to vanish from the scene, but morals continue on.

Modern humanism is essentially amelioristic. It has faith in progress.

It holds that by dint of human energy the fundamental goods of life may be enhanced. These goods are the classical trio—truth, beauty and morality. They are known by their effects—their roots by their fruits. Just as truth is a quality of a human thought, so morality is a quality of a human act. Both qualities find the test of their validity in the satisfactions of men. Morality becomes then a matter of consequences. That plan of action is right which mediates in the direction of the most satisfactory state of experience, or, to put it more objectively, contributes most to man's adjustment to reality.

Humanism is a philosophy of life. All philosophies, like all religions, must square themselves with the facts of science. They may use stones that the scientific builders reject (and there are such), but they reject at their peril stones that science uses. The philosopher does not live in a world apart; he only seems to. Though he fails to recall what he got into the bathtub for, that is only one of the embarrassing by-products of his occupation with abstractions. Philosophy is general in its outlook; sciences are particular. The function of the philosopher is the integra-

tion and interpretation of all knowledge. His speciality is "*weltanschauung*."

It is a favorable omen, though not unattended with dangers, when, as in these latter days, philosophers are cultivating a more intimate acquaintance with science, and scientists are weighing the effects of their findings on prevailing modes of thought. The cult of the scientist-philosopher is in the making—a cult to which science is more than a vague generalization and philosophy more than verbal technicalities. Eddington specializes on the nature of nebulous galaxies and spherical surfaces of space-time, but his lectures do not quail before the baffling problems of mental function and revealed religion. Millikan and Compton spend their days in intimate communication with electrons, quantum discharges and cosmic rays, but they step out of their scientific rôles long enough occasionally to enlighten the cohorts of religion and morals on such doctrines as libertarianism and divine immanency. On the other hand, Russell comes into the picture from the side of philosophy. He surveys the work of Compton, Millikan, Heisenberg, Schrödinger and Bohr on the internals of the atom, and then tells the world that, reduced to lowest terms, it is nothing but a series of events.

Few recent discoveries in physics or in any other science have so challenged the imagination of thoughtful persons as have those regarding the nature of the atom. And few conclusions have so ruffled the complacency of scientific thought as has the principle of indeterminacy. This principle is being interpreted as undermining the very foundation of classical physics, the law of causality. Friends of religion and morals are hailing the new theory with undisguised enthusiasm. The world now seems to be free from the chains of physical causation and man's spirit given wings. Free will comes into its own again and something akin to free spirit appears to be operating in the innermost

recesses of the atom and so at the very heart of the universe.

An atom no one has yet directly observed. It is an inference. The physicist studies the effects of radiation and from the seen he builds a picture of the unseen. The picture is usually that of a mechanical model. It portrays the atom after the manner of a planetary system. A proton acts the part of a sun and electrons are the planets. The simplest atomic system is presumed to be a proton with a single electron. This is the atom of hydrogen. Atoms of other elements are made by the simple addition of electronic satellites.

The so-called principle of indeterminacy has been stated as follows: An electron may have position or it may have velocity, but it can not in any exact sense have both. This statement looks innocent enough, but it has led some writers to assert that the principle involved ranks in importance with the principle of relativity. If true, it means a denial of determinism in the sense that "the data required for a prediction of the future will include the unknowable elements of the past."

Many of those who seem competent to form judgments betray some hesitancy or reservation in committing themselves to the theory. There is quite clearly a doubt, and in some intelligent quarters a considerable doubt, as to whether the new view will be able to maintain itself in this rapidly changing region of knowledge. Eddington is rather strongly inclined to accept it. "It is a consequence of the advent of the quantum theory," he says, "that physics is no longer pledged to a scheme of deterministic law. Determinism has dropped out altogether in the latest formulations of theoretical physics and it is at least open to doubt whether it will ever be brought back" (1929). As late, however, as 1927 Einstein wrote: "It is only in the quantum theory that Newton's differential method becomes inadequate,

and indeed strict causality fails us. But the last word has not yet been said. May the spirit of Newton's method give us the power to restore unison between physical reality and the profoundest characteristic of Newton's teaching—strict causality."

According to Bertrand Russell, the new theory amounts to a confession of scientific ignorance. That is, it may be a reflection of the inadequacy of measuring devices rather than an utter impossibility of measurement. Perhaps, as Schrödinger seems to suggest, an electron is not a particle but a phenomenon of wave interference, in which case there may be at one moment position without detectable velocity, at another velocity without detectable position, and yet all that goes on may be explainable in terms of wave mechanics.

In the light of the above pronouncements a degree of openmindedness is clearly justified with regard to this new theory. It would be well, however, to consider briefly the consequences of its truth and of its falsity, to recanvass some aspects of an ancient problem, still unsolved and perhaps insoluble.

Rightly or wrongly, determinism has filled the ranks of moralists with discontent. As the sciences of physics and biology and psychology have tied up the world more and more completely in causal connections, the moralist has persistently fought for a region apart where he could breathe in some measure the pure air of freedom. His suffocation has been aggravated and his alarm increased by the moral bankruptcy of those who find no room for ethics in a deterministic world. If all activity is naturally caused, including human activity, what place remains for moral responsibility? the query goes. And if an agent is not responsible for his action, what is the meaning of right and wrong?

In comparison with its alternative, the doctrine of determinism has been unduly maligned. As a matter of fact, the point

of view of thoughtful leaders in social administration has been gradually shifting for some time in its direction. In criminology these leaders increasingly incline to the belief that the offender is a machine defectively constructed or out of repair. In education they inveigh less and less against the wicked aberrancy of young perverted wills, and look upon their charges in the guise of machines in need of a mechanic. The most vicious criminal becomes simply a venomous serpent with danger written in his social contacts. One does not berate the rattlesnake for his offense. One does not regard him as personally responsible. But his act is wrong, nevertheless, as judged by its consequences, and the foes of wrong react in natural manner to prevent its recurrence. Under the sway of determinism this poisonous creature may logically be executed, he may simply be incarcerated, or he may be subjected to measures of reform. Most significantly, however, reform replaces vengeance as an objective, and sympathetic insight goes hand in hand with remedial treatment according to the causal law.

This view will be charged with a degree of inconsistency. An objector may urge that this method of treatment violates the freedom of the will. The reformer, it may be contended, is a *deus ex machina* surreptitiously introduced to make the system operate. This, however, seems not to be the case. The reformer is part and parcel of the system of causation in which the criminal also is enmeshed. He reacts as naturally in opposition to crime as the offender toward it. He himself is indeed a natural force for righteousness.

The moral ideal, according to this view, seems in last analysis to depend for its safety in part on the existence of atomic-structured brains that react selectively to moral qualities. How explain a positive reaction of a human organism

to right and a negative reaction to wrong? How explain the positive reaction of a lower organism to light and its negative reaction to darkness? All organic activity, according to the determinist, regardless of complexity, is an expression of natural causation. In accordance with natural causation the activity pattern may easily be modified in higher organisms. By physical and social heredity the conservators of the moral ideal are known to reproduce their kind. Educational institutions and other agencies of human welfare are recognized means to this end. But there is no guarantee that the world is safe for morality or democracy or any other social end. Evil is as real as righteousness. The devil incarnate breathes destruction in the midst of things. The spirit of noble living sits upon his neck and enjoys a triumph for the moment. But ultimately, what? One finds the determinist's answer only in terms of a courageous faith in the cosmos. In the last analysis he, as moralist, is obliged to trust the universe.

The modern program of social uplift leans on mechanism. In mechanism it not only places its reliance; with mechanism it also has a comfortable alliance. The new principle of indeterminacy, on the other hand, subjects this program to the mercy of caprice. The law of conservation of energy passes with the law of causality. The future no more grows entirely out of the past. It may now grow *ex nihilo*. The problem of creation is solved. Pure novelty leaks into the world, and the days of magic and miracle have once more returned.

Insofar as human activity is exempt from the reign of causality, insofar is it exempt from the scientific technique of modification and improvement now in vogue. What consolation, then, does the principle of indeterminacy offer to world-anxious souls? If the cosmos in its atomic recesses denies the causal law,

that kind of cosmos must of course be trusted. In the mass it still is known to act lawfully except for an error inappreciably small. Insofar, however, as it is capricious, an additional unknown is introduced into the equation of life. The possibility of prediction is thereby curtailed, the strain on faith is correspondingly increased, and confidence in cosmic support is inevitably weakened.

No one has argued more brilliantly for indeterminism nor with less pretense of proof than William James. To him free will was a "cosmological theory of promise," just like the absolute or God. James anticipated the present topsy-turvyness of scientific theory and its relation to our problem when he said a quarter of a century ago: "But nature may be only approximately uniform; and persons in whom knowledge of the world's past has bred pessimism (or doubts as to the world's good character, which become certainties if that character be supposed eternally fixed) may naturally welcome free-will as a *meliaristic* doctrine. It holds up improvement as at least possible; whereas determinism assures us that our whole notion of possibility is born of human ignorance, and that necessity and impossibility between them rule the destinies of the world." As truly also, one may say, is retrogression a possibility under indeterminism, for novelty knows no favorites and chance is marked with supreme indifference.

The moralist, proceeding on his fundamental presupposition that nature is improvable, plies her with remedial measures. Changes occur for the better. Evils are indeed remedied. Is the achievement his or nature's? Both, of course, for man is a part of nature. With pride have saints regarded themselves as instruments of God. With no less pride may the moralist become an instrument of nature.

But he is also in some measure an in-

dependent agent. No one suspects that the oxygen atom, when assuming polygamous bonds with two atoms of hydrogen, is entirely drawn thereinto by the rest of the universe. The rest of the universe may in familiar fashion oppose or abet the union. But if the marriage is consummated, the atoms have themselves in part to blame. Causality does not bring about their union, for in the best current tradition of science causality implies no force. What does it do, then? Indeed, it does nothing. Similarly, any other law of nature. The law of gravitation does not cause a sparrow's fall. Natural laws are merely descriptive. They are as inert as a mathematical formula. The law of causality expresses the fact of customary sequence among events. B follows A. That is causality. Why B instead of C or D? Why anything at all after A? There is no answer in the principle of causality.

To discover what hydrogen does in the presence of oxygen explains in no way the doing. The event is simply found

by science and recorded *post rem*. Do atoms, like the moon, shine from borrowed light? Are they mere unwinding clocks? What principle of rationality requires one to believe that energy is forever borrowed from elsewhere, or from some single pervasive source? Why not a myriad sources? The secret of that which is observed is hidden away in the elements themselves, for aught that science teaches. Thus are oxygen and hydrogen said to have certain ways of acting, certain modes of behavior. Refer to them as bonds, or affinities if you like. These are theirs, attributable, so far as known, to nothing elsewhere. And, if the simplest element conceivable reacts independently in the simplest way possible toward any other element, there is freedom of action. Freedom of action is freedom to act. It means the opportunity to act in accordance with one's nature, the opportunity to be oneself. External determination, not internal, means the denial of freedom.

Why, then, the cheers for indeterminism?

RADIO TALKS

By AUSTIN H. CLARK

U. S. NATIONAL MUSEUM

THE use of every new medium for the diffusion of information necessitates the development of a more or less highly specialized technique in order that its potentialities may be utilized to the greatest advantage. The progressive advancement of the magazines and later of the modern newspapers has now been followed by the perfection of the radio as a means of imparting information to an increasingly large section of the public.

As a vehicle for the diffusion of information, other than news of immediate and pressing interest, the radio is still largely in the experimental stage, for there are as yet no generally recognized principles comparable to those governing writing for the press to which radio talks are made to conform.

One difficulty in the way of formulating and enforcing rules governing radio talks, especially talks on academic or scientific subjects, is that the personnel of the radio stations seldom feel themselves at liberty to speak with the requisite frankness to those who appear at the stations, while at the same time the speakers themselves know little or nothing about the inherent peculiarities of the radio.

Another thing is that most talks at present are simply individual talks by various speakers who reappear at the station at irregular intervals—if they are invited to reappear at all. Few of the more important stations make a specialty of talks. So there is no incentive for studying the subject in the thorough and detailed manner in which the presentation of news in the press has been studied.

But the possibility of increasing the proportion of talks in their programs is

now interesting many stations, and in addition several organizations are engaged in planning series of talks which, through their appeal to the public at large, shall be of real value to the stations for which they are given.

The preparation of a radio talk which will meet with general approval on the part of the public, please the station from which it is given, and reflect credit on the speaker, is no easy task. It involves the cooperation of at least two people, in addition to that of the censor of the station from which it is to be delivered. It demands strict adherence to a number of different limiting factors which do not apply, or at any rate do not apply with such force, to items of similar length intended for publication.

In a radio talk the opening paragraph must include something sure to interest the listener so much that he or she will continue to listen. For instance, suppose that I am giving a talk on "The Cow-bird" and I begin, "Our cow-bird, like most cuckoos, the honey-guides of Africa, some weaver-finches, some hang-nests, the rice-grackle, and a South American duck, and according to recent information one of the paradise-birds, lays its eggs in the nests of other birds which hatch these eggs and raise the young," the number of listeners will be reduced to the vanishing point long before I have reached the end of the sentence.

In the first place, the title—"The Cow-bird"—is too grimly prosaic and means nothing to most people. In the second place, the long string of wholly unfamiliar names of foreign birds would cause the mind to skid unpleasantly and finally to run off the road entirely.

But if I change the title of the talk to

"Abandoned Bird Babies" and begin "Those unfeeling mothers who leave their little babies upon the door-steps of prosperous people's houses have their counterparts among the birds," etc., I shall be able to follow it up with a very considerable amount of information, and many people will learn that there are many different kinds of parasitic birds of which our common cow-bird is a typical example.

A radio talk must be so written as to be an elaboration of the idea conveyed in the first paragraph. It must be written about a single main idea to which all the other ideas expressed are subordinate, or of which they are explanatory. A talk including several diverse ideas or sets of unrelated facts leaves little impression, and what impression it does leave is always unfavorable. A radio talk must be a closely knit unit from beginning to end, and the last paragraph must be in every way as interesting and as strong as the first so as to stimulate a desire for more talks from the same source.

The composition of a radio talk is therefore essentially the same as that of a newspaper article. But there is one very important difference. While a radio talk must be a complete unit from beginning to end, and the last paragraph must be as strong as the first, a newspaper article must be so written that the editor, if pressed for space by some unforeseen occurrence, can clip off a series of paragraphs up to about half the total number without affecting the unity of the subject-matter remaining.

The subject-matter in a radio talk must be presented in a more or less condensed form. In a lecture the subject-matter must be well diluted, for otherwise the audience will tire. In the case of a lecture the audience is only partly occupied in listening to what is being said; a considerable portion of the attention on the part of the listeners is taken up in watching the mannerisms and subconsciously appraising the personality of

the speaker. The audience listening to a radio talk is to all intents and purposes blind; the visible mannerisms and the personality of the speaker are wholly eliminated, and the listeners are entirely occupied in hearing what he has to say. The result of this is that quite as much information can be conveyed in a radio talk of fifteen minutes' duration as in a lecture occupying an hour.

All radio talks should be written in such a fashion that they are suitable for subsequent publication as newspaper features or magazine articles, and also suitable for assembling in the form of pamphlets or small books which will meet with a ready sale. If a local newspaper will not consider printing any given radio talk—at least in a more or less condensed form—that talk should be dropped in the waste-basket and another written.

In any radio talk the word order is a matter of the very greatest importance. The words must be so chosen and so arranged that the sentences shall flow as smoothly as possible. Words commonly omitted in speaking and often in writing, particularly "that," "the" and "and," must always be included. In conversation facial expression supplies many missing words, while in reading there is always time and opportunity for inserting them. But the loudspeaker has no facial expression and allows no time for thought.

It is impossible to avoid the occasional use of more or less unusual and unfamiliar words. Such words should always be preceded by several familiar and preferably short words which can not be misunderstood in order to throw the unfamiliar words into relief and thereby to facilitate their comprehension.

For instance, if I should begin a sentence "Paradise-birds are confined to New Guinea and a few adjacent islands where," etc., very few would understand what I was talking about. But if I said

"Those strange birds, of which the males are dressed in varied styles of brightly colored plumes, known by the name of paradise-birds, are to be found only in that great island called New Guinea and on a few other near-by islands" quite a number of listeners might possibly become interested.

In radio talks the personal touch is always of the greatest importance. Whenever possible talks should be given by some one with a direct personal association with the subject.

Historical talks, no matter by whom they may have been written, should be read by a person related to some one directly concerned with the event or events described, or to the person whose exploits are featured. If published, such talks will appear under the name of the real author, with a mention in a footnote or elsewhere of the one by whom they were read.

Talks on the natural sciences should always be by some one personally familiar with the subject, and preferably by some one whose name has been connected with the subject in the newspapers. Definite evidence of familiarity with the subject should be given in the form of personal anecdotes or otherwise.

In introducing the personal touch the word "I" should be scrupulously avoided. There is something subtly disconcerting in hearing a loudspeaker describe itself as "I," although no one objects to its calling itself "me." This is the reverse of that animistic principle through the operation of which, in such languages as Russian, masculine nouns referring to living beings lack the accusative case.

In historical talks all the individuals mentioned should be adorned with the halos—or the horns and cloven hoofs—which the passage of time has conferred upon them. All historians know that history is strongly tinged with mythology; but history, on the basis of the

actual facts, would never be acceptable to the great bulk of the public. Belief in the superman is inherent in all of us. We know that personally we are not supermen. But we like to believe that our ancestors were, and we like to hope that some of our descendants may achieve that status.

Nothing of a controversial nature should ever be permitted to appear in any radio talk having anything to do with any form of science. The country swarms with people to whose philosophy science in any form is heretical and abhorrent, and whose chief delight is to seize upon some minor controversy, magnify and grotesquely distort it, and on the basis of the absurd result endeavor to discredit science, and learning in general, in the eyes of all who will listen to them. Such people are most numerous in the very areas where the radio is exceptionally valuable as a vehicle for general education.

Especially in the sparsely settled sections of the country the radio ghost is a factor demanding respectful consideration. In the days of our grandparents when ghosts were common it was well known that all ghosts were possessed of a most unfriendly and often vindictive nature. With the passing of the flickering candle and the oil lamp, and the coming in of the steady and brilliant illumination of the present day, ghosts have disappeared.

However, the basic psychology that made the ghosts possible we still retain. No matter how familiar it may be to us, the disembodied voice from the loudspeaker is possessed of certain ghostly attributes, or rather is capable of acquiring ghostly attributes. The radio ghost shows itself at once when gloomy or ghastly information issues from the loudspeaker. When heard from a loudspeaker information of an unpleasant nature is many times as unpleasant as the same information would have been if heard from a friend or read in a news-

paper. Proper respect for the radio ghost is essential in the preparation of radio talks. We must remember always to make radio talks as interesting, bright and cheerful as possible in order to overcome the ghostly attributes of the loudspeaker.

It must be constantly borne in mind that the voice from the loudspeaker is to a large extent dehumanized and ghostly, and every effort must be made to overcome this effect. A few speakers are able to convey sufficient personality through the voice to overcome this of themselves. But the simplest way to overcome it in a series of radio talks is by the more or less frequent introduction of dialogues.

Dialogues are always popular. Talks on distant regions popularly supposed to be wild are most effective if they are presented as dialogues between the traveler and a young lady with a voice that sounds as if she were very pretty, who asks more or less silly questions. In order to give the necessary unified effect, the entire dialogue should be written by one person. Dialogues should never be attempted without adequate rehearsal. A plain matter-of-fact dialogue is worthless. But the development of the essential "come to me" quality in the feminine, and the "here I am" quality in the masculine, voice requires practice.

After a talk has been written out to the complete satisfaction of the prospective speaker and of his friends and close associates, the easy and pleasant part of the work is over. Now comes the part which, though absolutely essential if the talk is to be a real success, is anything but agreeable.

All radio talks before delivery must be edited by some one with no knowledge of the subject-matter but thoroughly familiar with the difficult and highly specialized technique of writing for popular consumption, who will not be afraid to commit the most fearful sort of butchery if necessary.

In scientific writing a series of facts is presented, and then the conclusions drawn from those facts are given. In a radio talk, as in a newspaper article, this procedure must be almost completely reversed. It becomes almost impossible, therefore, for any one trained in science to prepare a good radio talk without assistance.

If no trained writer is available, a good plan is to read a prospective radio talk to some one with not more than a high-school education, and then find out from him or her what is the chief idea that has been conveyed—if any.

The chief idea conveyed by a radio talk to an average person is often most disconcertingly at variance with the main point of interest in the opinion of the writer. Nevertheless, painful as the process may be, the talk should be rewritten along the lines suggested by the listener. In addition to recasting the style of a radio talk and rewriting it in good radio American, the editor has certain other responsibilities.

Everything that can possibly be interpreted as advertising in any form must be eliminated from all radio talks. This includes mention of books, magazines, newspapers, merchandise of all kinds, transportation agencies, steamers, hotels, institutions supported by private donations or public funds, etc. Great care must be taken to see that this rule is rigidly upheld and inflexibly applied to every talk. The unintentional inclusion of some form of advertising is perhaps the most frequent sin committed by writers of radio talks.

After the editor has done his part, the next thing to be considered is the performance of the speaker before the microphone. The announcers will be found to have certain very definite ideas on this subject.

All radio talks must be written out in full and read from a clean manuscript. The station should be provided with a carbon copy of the manuscript well in

advance, so that if something should happen to the speaker one of the announcers may read it at the appointed time.

All radio talks must begin and end exactly on the second, if the good-will of the station is any consideration. It is as much of a crime to end a talk a few seconds too soon as it is to run over the appointed time.

It is almost needless to say that the manuscript must be read through smoothly without a hitch or break from beginning to end, and that every word must be distinctly pronounced. But the reading must not be mechanical. The voice must be conversational in quality, and must convey the impression of a lively interest in the subject-matter. But any oratorical attempts are taboo—oratory oozing from the loudspeaker is always ridiculous, as many politicians have learned.

If a word be mispronounced or omitted, no correction must be made; the talk must continue as if nothing had happened. On some people the correction of a word or of a phrase make a more lasting impression than anything else in an otherwise perfect talk.

Clearing one's throat or coughing during the delivery of a talk are absolutely unforgivable offenses which no excuses can justify. No one addicted to these diversions should ever be permitted to appear before the microphone.

By no means every one can give a radio talk as it should be given. The quality of the voice is of very great importance. What is commonly known as the New England twang is the vocal quality which is best adapted for radio speaking. The various overtones and the nasal effect, mercifully smoothed down by the loud-speaker, seem to produce a clarity found in no other type of voice. It is rather curious that a bad cold sometimes greatly improves a speaker's voice from the radio point of view.

At the radio station the speaker's atti-

tude toward the announcer must approximate as nearly as possible that of a freshman on probation toward the president of the university, at least until the talk is over.

Perhaps the commonest fault in radio speaking is the too rapid reading of the manuscript. A talk with a duration of fourteen minutes and thirty seconds—that is, a fifteen minute talk—should consist of not more than two thousand words.

The speaker must remember that very few of his hearers are sufficiently familiar with his subject to enable them to follow him if he talks with the usual rapidity. Furthermore, two people talking face to face always to some extent read each other's lips and expression, which greatly helps in carrying on a rapid conversation.

Inexperienced speakers—indeed nearly all speakers—should be attended at the studio by a friend provided with a slip of paper bearing the word "SLOWER" in large letters which can be shown the speaker in case of necessity. Very few of those speaking for the first time can get through their talk without two or three admonitions, and some must be carefully watched on every occasion when they face the microphone. Occasionally a new speaker can control his speed, but develops a pathetic quaver in his voice. The sight of a large and conspicuous pin moving toward his arm will usually result in correcting this condition.

In any series of radio talks much depends upon the manner in which the speaker is introduced. The transition between the regular announcer at the station and a speaker from a museum or any similar organization or establishment is so abrupt that it must be in some way bridged.

The most effective means of bridging this gap is through the appointment of some suitable person whose duty it shall be to introduce every speaker in the

series. The station's announcer then simply mentions the special series of talks and introduces the museum's announcer.

The latter, speaking for sixty seconds, briefly states in popular language who the speaker is, and endeavors to explain why the talk is worth hearing. The interest attaching to the talk should be explained both in terms of the talk itself, and in terms of the special fitness of the speaker to discuss that particular subject. In other words, it must be an effective effort to "sell" the talk to people who are all primed to enjoy fifteen minutes filled with, to them, delightful jazz.

The speaker, of course, looks over the short manuscript which will be read by the museum's announcer in advance in order to make sure that the statements therein made are correct, and in order to readjust his personal feelings to the exigencies of the situation.

Speakers, especially when widely known, should always be introduced as "Mr." and never as "Doctor" or "Professor." Academic titles, such as Doctor of Philosophy, Professor of History, Curator of Mammals, etc., which of course should be mentioned in the introduction, should follow the name. Whatever social or commercial value academic titles may have within academic circles, outside of these circles they are more of a liability than an asset. They are as distasteful to captains of industry as they are to laborers.

The reason for the popular prejudice against these titles in this country (and also in England) is easy to see. To most minds they represent an attempt to create social distinctions along lines in which such distinctions are purely artificial.

In academic circles, and in the concentric rings about those circles, addressing a man as "Doctor" implies a certain respect based upon the academic significance of his profound knowledge of

his particular subject—in other words, based upon the intra-academic power which he possesses by virtue of that special knowledge. In the world at large, outside of academic circles, these titles represent nothing in terms of power. They are therefore wholly meaningless, and hence are often regarded as ridiculous.

Beside the writing, editing and presentation of radio talks, there are other things to be considered in connection with them.

Arrangements may sometime be made with local newspapers to illustrate radio talks. This has been tried in various places during the past seven years, chiefly in connection with talks given from stations owned by newspapers. The pictures illustrating the talk, made up into full or half pages, are published in the issue of the paper immediately preceding the talk, and the listener looks at them while the talk is in progress.

The preparation of a really good radio talk necessitates the expenditure of a very considerable amount of time and energy. And in addition most authors undergo more or less keen mental suffering when they become aware of the utter lack of appreciation of their literary abilities, and of consideration for their feelings, on the part of the editor. So it is only fair to the author to see that the best possible use is made of his manuscript after the talk is delivered.

If the radio station from which the talk is delivered happens to be operated by a large daily paper, arrangements may often be made to print the talk in full in the first issue following its delivery. This has frequently been done. In other cases a good talk is easily placed with some newspaper syndicate or magazine.

After the delivery of a talk a number of good clear photographs suitable for reproduction by the half-tone process should be assembled for illustrations.

The talk can then be offered as a full-page feature article to newspaper syndicates, or to the larger individual papers, or sent to certain magazines.

Generally speaking, a radio talk has no great cash value, though many have been sold for good prices. On the other hand, practically all of them are worthy of publication in some form or other. In not a few cases a talk, as it was read, is not easily marketable, but certain individual items in it, if each be provided with an appropriate picture, will meet with a ready sale.

It is always interesting to trace the history of a radio talk after publication through a clipping bureau. Some talks delivered in Washington and subsequently published in full later reappeared to the extent of a page or more in the *Literary Digest*. Excerpts from these and others later came in from daily or weekly papers in India, South Africa, Australia and New Zealand. In one case an excerpt from a radio talk that was read in Washington appeared two years later as a news item in one of the Washington newspapers under a Sydney, New South Wales, date line.

The publication of a radio talk successfully overcomes that feeling of vacuous insufficiency which many experience after their first encounter with the microphone. It also serves, in practically every case, to reestablish amicable relations between the speaker and the editor. In any well-planned series of radio talks the reading of the manuscript should be regarded simply as the beginning of extensive publicity for the included subject-matter.

The effect on a new speaker of a fifteen minutes' monologue before the grimly unresponsive microphone in a sound-proof chamber where people slink about like so many nurses in an operating room is always interesting to observe. The feeling of elation experienced by many after somewhat unexpectedly surviving

the ordeal renders them especially susceptible to flattery.

Every radio talk brings in letters and telephone calls from enthusiastic listeners who are quite sincere in their praise of what was said, and in their admiration for the speaker. Other letters come in from people, chiefly elderly women, who are conscious of the radio ghost lurking in the loudspeaker, and after listening to a talk relieve their feelings by writing to the speaker.

These letters must not be interpreted as representing the sentiment of any appreciable proportion of those who heard the talk. They are simply evidences of emotional reaction on the part of a very few individuals who happen to have—or wish to appear as having—much the same interests as the speaker. A dissertation on the philosophy of Anaximander delivered in Greek would result in the receipt of quite a number of enthusiastic letters from people who wished to be considered as understanding what it was all about. Letters and telephone calls are pleasant to receive, but they mean little or nothing.

Much as lepidopterous moths struggle to secure a place as near a light as possible do human moths endeavor to intrude themselves into the light of the publicity afforded by the radio. Just as soon as it becomes generally known that a series of radio talks is in preparation, pressure for place in the series from all sorts of unexpected quarters will begin to manifest itself.

This pressure for place arises from three sources—*first*, propagandists and egotists of all descriptions, grading into, *second*, cranks, still more diversified; and *third*, politicians, usually more or less closely allied with the propagandists. Politicians as a rule are quite reasonable and cause no trouble. Conversation with them, of course, must be entirely along the line of a possible loss of votes. Cranks are also easy to deal with. In

this case the usual procedure is to refer them to the manager of the station who, poor chap, is very frequently called upon to deal with such people. While it may seem unkind to send the cranks to the manager of the station, you will find that the manager himself has been responsible for the appearance of some, at least, of the propagandists in your office. In this way the account is balanced. The director of any successful series of radio talks must possess the ability to deny people a place in his series in such a way as permanently to discourage them without incurring their active hostility.

There is another phase of this subject which is of vital importance. Volunteer speakers on all possible—and many impossible—subjects appear more or less frequently at all radio stations. Many of these are recommended to the managers of the stations by influential people with no knowledge whatever of the fitness of the supplicant to discuss the subject on which he professes to be an authority, and many are exceedingly persistent.

Every large university, or other institution of learning or culture, should be in close touch, at least informally, with the more important radio stations in its vicinity, and should at all times be ready and willing either to supply competent

speakers if requested by the stations, or to pass upon the fitness of any speaker if asked to do so by the station managers. Lack of the proper cooperation between the radio stations and the local universities, museums and similar organizations has in the past resulted in the occasional appearance on radio programs of talks that reflected no credit on any one.

From what has been said above it is evident that successful radio speaking is an accomplishment that involves a curious mixture of the ability to write in modern newspaper style and the ability to address the microphone with all the enthusiasm and charm of a popular after-dinner speaker, combined with a submissive humility often conspicuously lacking in outstanding orators and writers.

Furthermore, it usually involves the cooperation of several different individuals and agencies who must work cordially together for the common good.

The development of a corps of really first-class speakers and the organization of the necessary assistance for each is now under way in various sections of the country, and at the present rate it will not be long before the radio becomes as powerful a factor in our social system as are the newspapers to-day.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

THE WISDOM OF LIVING THINGS

By Professor EDWIN G. CONKLIN

PRINCETON UNIVERSITY

EX-PRESIDENT COOLIDGE is said to have used as a motto this rhyme:

A wise old owl sat on an oak,
The more he saw the less he spoke,
The less he spoke the more he heard
Why can't we be like that wise bird?

Fables in all ages have attributed to various animals wisdom, cunning, ingenuity, patience, deceit, fidelity. Such fables have an element of truth in them or they would not appeal to us. At least we can say that many animals behave as if they had these qualities. In a notable book, entitled "The Wisdom of the Body," Professor Cannon has recently emphasized the remarkable capacity of the human body to do the right thing at the right time. But all living things, plants as well as animals, do useful things and meet emergencies, often in ways that conscious wisdom can not excel. Even the simplest and smallest animals and plants avoid enemies, repair injuries, neutralize poisons, meet depressions, resist death and manage to leave offspring in the most ingenious and complicated ways.

Even the microscopic cells of our own bodies meet emergencies in ways that seem intelligent and purposive. If you are practicing sun-baths you probably know how painful sunburn can be, and yet in a short time your skin becomes brown and does not burn, because the microscopic cells of the skin form pigment which protects them. Plants often protect themselves from salt spray or desert dryness by growing a thicker epidermis, just as friction or many chemicals cause our skin to thicken and be-

come calloused, thus protecting the deeper lying parts.

Warm-blooded animals have extraordinary ability to preserve a uniform body temperature. In hot weather the skin or mouth glands pour out fluids, which by evaporation cool the body; if it is too cold, shivering and muscular activity increase the internal temperature. In winter horses grow a thicker coat of hair, bears curl up in some protected spot in their winter sleep, and if their internal temperature approaches the danger point, they wake up, exercise and even seek food to increase their temperature. Bees exposed to cold weather gather into a dormant cluster in the hive, keeping one another warm. If those at the surface get too cold they become active and burrow into the middle of the cluster; if the temperature at the center of the cluster falls to about 57° F. they all wake up, raise their temperature by muscular work, take in food and then go to sleep again.

All animals and plants have more or less ability to repair injuries. Many plants can be cut up into fragments and each piece will retain the power of producing a whole plant. Many worms can grow new heads or bodies when these are cut off; salamanders and lizards can grow new tails or legs, and all living things have the power of healing wounds, which is by no means a simple matter.

Even more remarkable is the capacity of many animals for neutralizing poisons. If minimal doses of serpent venom are injected into animals they form an

antivenin which neutralizes the poison, and a peculiar antivenin is formed for each kind of venom. Thus guinea-pigs native to South America may be made immune to the venom of cobras from India, though never before in all their past history have they had any contact with each other. In a similar manner, bacterial poisons of disease germs are neutralized by the formation of different kinds of antibodies or antidotes. The violent toxin formed by diphtheria germs is counteracted by an antitoxin formed in the body of the victim of the disease. The same is true of the poisons formed by many other disease germs, each peculiar poison leading to the formation of its own peculiar antibody. In this way man and animals acquire immunity to many diseases, if only the poison does not act too quickly to permit its antidote to be formed. Artificial protection may be had by using the antitoxins formed in the bodies of other animals, but no chemist has ever yet been able to synthesize these chemical substances in his laboratory.

Consider further the chemical and physical processes of digestion, assimilation, respiration, excretion; of enzymes, vitamins and hormones which have such profound effects on health, growth and development. How have lowly plants and animals learned the secrets of such subtle chemical and physical processes that intelligent man has only just now come to the place where he can appreciate the great importance of these, but in most cases can not yet artificially duplicate them?

Most of these cases of unconscious wisdom on the part of living things are in the nature of useful responses to contingencies which may or may not arise. They occur only in response to a present need; they are individually acquired fitnesses.

Another large class of fitnesses are inherited. They develop not to meet a present need but for future use. For

example, think of the fitness of the eye for seeing and of the ear for hearing, although in higher animals both are developed in the absence of light and sound. Consider the fitness of the nervous system for receiving and transmitting stimuli; of the organs of digestion, circulation, respiration, excretion for their particular functions; the fitness of muscles for movement, of the skeleton for support, of the various glands for forming necessary secretions. All these and hundreds of other adaptations are inherited in anticipation of future use, although they may later be perfected by use. Other inherited structures fit animals and plants for some particular place in nature, such as the fitness of fish for life in water, of birds for flying, of moles for burrowing. Man has only recently conquered the air, but many insects, reptiles and birds did this millions of years before man appeared, and they are even now teaching us skill and efficiency in flying.

Some of the most extraordinary fitnesses are found in the interrelations of organisms with one another. All the principal methods of offense and defense known to man have been in use by animals for many millions of years. Animal armor, horns, tusks, swords and arrows; armored ships and land tanks; tear gas, camouflage and "playing 'possum,'" indicate how little man has invented that is entirely new in principle, and the failures as well as the successes of these animal experiments in offense and defense should be of value to the human race at this particular time.

Flowers flaunt their colors, spread their odors and secrete their nectars, not to please themselves or man but to attract insects that carry pollen from flower to flower, and thus bring about cross-fertilization. The phenomena of sex attraction, ranging all the way from cells to psychology, are among the most marvelous of all fitnesses. Consider the

remarkable structures and functions of the sex cells, their chromosomes and the methods of their division, segregation and recombination, upon which all the phenomena of heredity depend. Could the wisdom of man have invented anything more perfect or wonderful?

Finally, the infernal ingenuity of many parasites in holding up, entering, robbing and torturing their victims could not be excelled by human gangsters or mythical devils. Think of the malaria parasite that is transported from victim to victim by the high-powered mosquito, of the many transformations that it undergoes to enable it to get from the stomach of the mosquito to the salivary glands, where it lies in wait for the chance to get through the skin and into the blood of the victim that the poor mosquito bites. Hundreds of other similar cases of devilish ingenuity may shake our confidence in the universal beneficence, but not in the apparent wisdom of living things.

This bare recital of certain classes of organic fitnesses or adaptations gives no adequate account of the extraordinary extent and delicacy of such adjustments. Indeed, all life is, as Herbert Spencer said, continual adjustment of internal to external conditions. Of course plants and animals and human beings sometimes make mistakes; they are not always wise, but on the whole if they are given sufficient time they find the right answer to all their problems, or they cease to exist.

II

How have such fitnesses been produced? This is the greatest problem of life and evolution. Formerly it was generally believed that each and all of them were caused by supernatural design. But the fact that one design conflicts with another, that the fitness of a parasite is matched by a counteracting fitness of its victim would rather indicate that both devilish and angelic de-

signers were concerned. Furthermore, the innumerable ways in which plants and animals meet emergencies would seem to be no more supernatural than our own behavior under similar circumstances. Few, if any, scientists now maintain the supernatural creation, either of adaptations or of species.

Another type of explanation that is favored by some scientists and more philosophers is that all living things have some form of unconscious will, intelligence or wisdom that causes them to do the right thing at the right time. But such an explanation does not make plain the cause. It proposes a cause that is as inexplicable as the fitness itself; it substitutes a god within the mechanism for one outside it. It may be true in whole or in part, but it solves the problem only by shifting it to another field which is much more difficult of scientific examination.

Finally there is the solution proposed by Charles Darwin, namely, the elimination of the unfit and the survival of the fit. If all organisms vary in relative fitness and if those that are less fit are eliminated, while the more fit survive, there will be a continual drive toward fitness. There is no doubt that this is true and that this elimination of the unfit is much more extensive in germ cells and embryos, which we do not see, than in adults. This simple principle of Darwinism or natural selection does explain, as nothing else does, inherited adaptations of all kinds, though, of course, it does not explain the origin of the useful variations which are selected.

But classical Darwinism does not explain individually acquired adaptations where useful responses are made by animals and plants to conditions and crises which they never experienced before, such as acquired immunity to many strange poisons and venoms, regeneration of the lens of the eye of a newt after its extirpation, though this particular injury never could have occurred in

nature and the many other beneficial responses which organisms make to conditions which neither they nor their ancestors ever experienced before. In such cases there is no elimination of unfit individuals; the same animal or plant continues to survive and gradually acquires the ability to make the useful response. In many cases we know that this is done by a process of trial and error and finally trial and success. In short, all sorts of things are tried and, if they do not meet the situation, they are eliminated until finally something is tried that succeeds. This is an extension of the elimination of the unfit from persons to reactions and it does offer a formal explanation of all kinds of fitness, whether inherited or acquired.

Even intelligence and purpose in animals and man are explicable in the same way. In the development of behavior all kinds of actions and ideas are sorted by trial and error. Those that fail to give satisfaction are eliminated; those that succeed are retained. Whether it be cats learning to open a box, or man learning to solve problems, useful re-

sponses always have as their beginning a more or less rapid elimination of unsatisfactory ones. Human intelligence and purpose are the highest type of adaptation, and therefore all adaptations appear to us intelligent and purposive.

Here, then, is a mechanism for explaining the biological wisdom of plants and animals and man. But this solution of the problem is not complete, for it is based upon the unexplained fact that all living things are differentially sensitive, that is, they have the ability to distinguish between satisfactory and unsatisfactory conditions and can avoid the latter and select the former. This capacity of distinguishing between the satisfactory and the unsatisfactory, the useful and the useless, must be regarded as a fundamental property of living things, which can not at present be reduced to simpler terms. Thus we endow life at the start with the very properties which we seek to explain, namely, the capacity to distinguish and select, which are the beginnings of wisdom in all living things.

PUBLIC HEALTH PROGRESS

By H. S. CUMMING, M.D., D.Sc.
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WITHIN the memory of many of us our race has passed through an epoch-making period, unequaled in the annals of history. In its beginning little more was known of the cause, mode of spread and means of prevention of disease than in the early days of history. Synthetic chemistry was unborn. In applied physics the electric light and telephone were curiosities. In transportation the first electric train was used. In sociology there was but the first awakening of the public consciousness of the duty and necessity of community effort and of the close interdependence of the

different classes of society. We have eaten largely of the fruit of the tree of knowledge. And into this great period came the world war and its immediate aftermath, the destruction of old landmarks in politics, in faith, apparently in all things that were.

The fever of war was apparently diverted into other fields of activity. The war itself had brought about the recognition of the necessity of group action in production, transportation and health, no less than in military movements; and, indeed, there was for the first time a consciousness of the depen-

dence of military success upon concerted action by the civilian population. Large sums of money and large powers were given for the purpose of improving the health and welfare of non-combatants.

Largely as the result of this increased consciousness of the importance of the public health movement having been awakened in the mass of our population, there has been a constantly broadening interest in the whole field. Not only has this been true among those elements interested in the humanitarian side, but, perhaps more important, industry and finance have been made aware of the vital significance of mental and physical well-being, not only to the individual but also to themselves and to the government. Leaders in industry and finance have had brought to them the enormous dividends from true research by competent personnel. During the same period, many countries have had an unprecedented era of prosperity for the masses and the accumulation of great fortunes by individuals and corporations.

As a result of recent discoveries in the sciences in their application to public health, and no less as a consequence of the realization of the interdependence of individuals and even of nations, that "none of us liveth to himself, and no man dieth to himself," that the strength of a people depends upon the moral, mental and physical health of its individuals, there has come a realization that the public health is influenced by environment, heredity, industry, economics, morality, education. The insanitary dwelling, the malaria stream, the diseased or idiot parent, the hazards of dust life, knowledge of diseases and how to avoid them, all come within the sphere of the present public health movement.

Nor is there justification for the artificial division of medical science into preventive and curative medicine. The object of public health work is to prevent

illness and pain and premature death. The interests of the people as represented by government are equally affected by helpless individuals, whether made so by heart disease, rheumatism, general paralysis of the insane, or by smallpox, plague or infantile paralysis. The research worker in the laboratory, the health officer in the field, and the surgeon or physician at the bedside are all directly or indirectly, consciously or unconsciously, public servants working for the public good. The ideal for which we aim is the application of every available means for the prevention of disease or injury and the provision of suitable treatment for all sick or injured. The problem is how this ideal may be attained with the greatest good to the common weal. The solution is not to be found by mathematical formulae, nor ecumenical council; it will differ in some phases in different states and cities, indeed, in each community.

The history of the control of typhoid fever which has been accomplished in the United States within the past 30 or 35 years is a splendid example of the effect of public health work. This control of typhoid fever was accomplished by the cooperation of all the health agencies of the country—federal, state and local. Typhoid fever, which formerly took an annual toll of more than 35 of each 100,000 persons in the population of the United States, is now responsible for the death of about 5 persons per 100,000 each year.

Diphtheria is one of the communicable diseases of which we know the cause and mode of transmission and for which we now possess a specific preventive, the toxoid or toxin-antitoxin mixture, and a curative agent of great potency, the antitoxin. We also have a reliable test, called the Schick test, which indicates whether or not a given individual is susceptible to the disease. The death rate from diphtheria has responded quickly to the medical discoveries of the

past few years. The use of diphtheria antitoxin gradually increased from 1894 to 1905. In the 5 years from 1906 to 1910 the diphtheria death rate in the registration cities was 24 per cent. less than the rate for the 5 years from 1901 to 1905. In 28 American cities for which the rates have been computed, the decline has been from about 116 per 100,000 in 1890 to 5.5 per 100,000 in 1930. This extraordinary achievement in public health will probably stimulate campaigns for the better control of other communicable diseases.

Studies within the past few years, which incidentally were made by officers of the Public Health Service, have shown that pellagra is a disease caused by improper diet and that the prevention and cure of the disease lie in the eating of a well-balanced diet. The identification of the human species of hookworm as the cause of a wide-spread anemia has resulted in a notable diminution of the preys of this disease.

Fifty years ago tuberculosis caused about 320 deaths annually in every 100,000 population. To-day tuberculosis causes less than one fourth of this number of deaths per 100,000. While the reduction of the death rate from tuberculosis has been undoubtedly due in part to natural causes, it is probable that much of the reduction has been the result of public health activities. Among the specific measures that have contributed to this result are improved and more accurate methods of diagnosis, the pasteurization of milk, the abolition of the common drinking cup and other utensils used in common, the inspection of meat products and improved housing.

Recent studies have developed a serum which is believed to be of considerable value in the treatment of scarlet fever. A test called the Dick test—named for the doctor who devised it—is useful for determining whether a given individual is susceptible to scarlet fever. It is believed by public health officers that this

test will be of material value in the control of scarlet fever.

The first whole-time county health unit was established in the United States in Yakima County, Washington, in 1911. Five hundred and fifty-one counties in the United States in 1931 were provided with local health service under whole-time officers. During the past 15 years the Public Health Service has undertaken a program of cooperative demonstrations in rural health work from which have come many sanitary and economic profits to the communities and an impetus for the development of whole-time county health service.

It is the consensus of opinion of public health workers that the most important developments of the future relating to public health lie in the growth and strengthening of local health departments or local health units whose functions are not only to bring about improvements through education, demonstration and enforcement of local health requirements, but also to insure their maintenance as well. With the development of the local health unit, whose personnel devote full time to their duties, it becomes possible almost immediately to expand the work into a general public health program, so that the activities are not confined to sanitation alone but also include the control of the acute communicable diseases, tuberculosis work, venereal disease prevention, malaria control, school hygiene, infant and maternity hygiene, and other special activities that are required by the conditions in the particular locality served by the local health department. This plan of work has proved uniformly successful, and public health authorities generally are in accord with the opinion that the extension of efficient whole-time service throughout the United States affords the best and most effective method yet devised for bringing to the men, women and children of this country the benefits of public health knowledge and its potential application.

WILL THERE BE AN AGE OF SOCIAL INVENTION?

By ARLAND D. WEEKS

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Two hundred years ago the question might have been asked if there was a future for mechanical invention; then probably no one saw a great field ahead for new mechanisms. At one time, even, in the history of the United States patent office its director proposed its closing on the ground that all the inventions possible had been made. But the field for mechanical invention proved wide, and for that matter probably is still boundless. Edison took out over 1,300 patents, which means that he saw at least over 1,300 mechanical situations that might be improved. The field of mechanical invention has been and will remain wide, for imagination plus irritability goes far. Scarcely a physical situation exists anywhere that is not a challenge to ingenuity for improvement. As people become discriminating, the number of mechanical situations that get on their nerves increases. The response is—better cars, better heating, better highways, better elevators, better footwear, better typewriters.

Just as there has been a field for mechanical invention, so is there a field for social invention? Just as invention flowed out of perception of mechanical deficiency, so will invention flow from perception of deficiency in social relations? Just as a mechanical way was invented by which the farmer escaped the discomfort of cutting grain by hand, so, for example, will a social way be invented to dispose of the operation of cars by drunken drivers? Just as a way has been found for keeping the physical bodies of flies from getting into our soup, so some day shall a social invention, analogous to a fly screen, protect us from "drives"? No end of social invention,

perhaps, once the attitude of attack on long-suffered nuisances and unpleasant time-honored ways is avowed.

But in contrast with social invention, mechanical invention has achieved prestige. People who clung to antiquated social concepts loosened up in favor of, say, fly screens. The astonishing assertiveness of the early steam engine somehow captivated the crude senses of the times and won for Watt a hearing that Mrs. Sanger has not yet secured. Many mechanical inventions, such as windmills, tractors and wrist watches, have psychologically been toys for adults and as such have had an entrée denied to Clarence Darrow in Tennessee. Eventually the public was won over to the idea of mechanical progress, having reformed entirely of its throwing of its Roger Bacons into prison or of guffawing crudely at its Fords and Langleys. Resistance to mechanical improvements as such has reached the vanishing point. The descendants of a stock that fought the use of umbrellas as impious and resisted the use of steel plows as poisonous to the soil now stand in line to see the new models of sixes and eights, and tell the hardware clerk where this tool and that device might be improved.

The mechanical progress concept was "sold" relatively early to the general public. The "talking point" in mechanical contrivances is now that of a new feature; while the "talking point" of a social relation is that of an old feature. Actual social invention is miles behind mechanical advance.

With social invention miles in the rear, what chance is there that it will ever catch up? May we look for two centuries of social invention as striking as

the mechanical progress of the two centuries next last past? Are we reaching a stage where we shall no longer, as has been done within living memory, throw into jail persons of socially inventive type? Shall we soon cease to line the fences, after a manner of speaking, to roar and simianize over the faults of new mechanisms of the social grain field and highway? Shall we soon see the day when the social inventor is not hurried towards the Siberia of disgraced joblessness, or breathless from flight from the guardians of free speech in our cities? In fine, shall we soon reach the state of tolerance for social invention that was reached for mechanical invention as the industrial revolution proceeded?

Some there may be who would deny the possibility that in number and utility social inventions can ever parallel the mechanical inventions of the past two centuries. With any such I would disagree. I believe that for every one of the great mechanical inventions there is the possibility of an equally ingenious and great social invention, and that for every one of Mr. Edison's 1,300 inventions there is possible an invention of the social type for the betterment of social relations and affairs. Bear in mind that social invention is still penalized, and that to cultivate a sense of conquest rather than to submit in patience is still unorthodox and revolutionary. With the shackles off social invention there would be no good reason to suppose that inventiveness would be less fertile for social progress than mechanical invention has been for mechanical advance. We have never yet hit our stride in social invention; never fulfilled the conditions, which are: a cultivated perception of undesirable conditions—a problem consciousness—and a sanctioned attack by logical imagination.

A writer¹ gives this list of some of the great inventions of the industrial revolution:

¹ Stuart Chase, in "Men and Machines."

Reverberatory furnace	Telephone
Galvanic battery	Gas engine (four cycle)
Paper-making machine	Phonograph
Screw propeller	Incandescent lamp
First commercially successful steamboat	Steam turbine
Stethoscope	Linotype
Milling-machine	First safety bicycle
Water turbine	Aluminum process
Electromagnet	Kodak
Locomotive perfected	Trolley car
Dynamo	Recording adding machine
Reaper	Motion picture machine
Electric telegraph	By-product coke oven
Revolver	X-rays
Electric motor	Radioactivity
Electrotype	Wireless telegraphy (high frequency)
Photography	Airplane
Steam hammer	Diesel engine
Turret-lathe	High-speed steel
Sewing machine	Airship
Rotary press	Tungsten filament light
Electric locomotive	Television
Machine gun	
Bessemer steel	
Dynamite	
Electric steel furnace	

Good wine needs no bush, and these great inventions need no broadcast. They with a host of others have made over the mechanical aspects of human existence. They are part of the record of human affairs. Can any such list be essentially duplicated by social inventions of the future?

Social invention will affect laws, regulations, constitutions, government, the distribution of wealth, administrative facilities, education, mental hygiene, economics, finance, penology, employment, international relations, courts. It will develop better techniques and connote vastly more intelligent operations on the social plane.

To state coming social inventions were to invent out of hand. Not much more can be attempted than to point to social disharmonies which in the nature of things should inspire the social inventor; and as to discover need is the beginning of invention it must be that none of us to-day can be capable even of indicating adequately the range of the objectives that will engage the energies of the Edisons of social invention of the future.

The spell of custom is so strong that we but faintly perceive the rectifications that might be made. We little dream of the gamut of laudable change possible in human relations. To-day we are in social outlook like the child born with a visual defect who assumes that distorted vision is normal. Thus there are those who say that war is inevitable because of the nature of human nature, and who in saying this are like those who knew that a boat could not be made to buck the current of the Hudson. In fact, the whole outlook toward social change and betterment strongly resembles the stodgy defiance of mechanical science centuries ago. Hence we know little of what lies in the sphere of social invention. But even with the low visibility of the field it is possible to point out a few objectives of social inventions which should compare not insignificantly with the major inventions of the industrial revolution.

Below are given some catchwords of social invention, these terms serving merely to focus attention on aspects of current affairs from which ingenuity might make a running start with prospect of superseding older practice, introducing refinements of design, or of projecting the larger engines and leverages of social reconstitution. The terms given will mean much or little according to the imagination of the reader. Thus, rotation of occupation might be conceived as alternating the rôles of sedentary bookkeeper and of traveling salesman month by month, or of scheduling rotations that would involve recurrent geographical change on the part of whole sections of population. The term is given, bare, and its connotation, reader, is left to you.

Over against, then, the mechanical inventions of the galvanic battery, paper-making machine, screw propeller, stethoscope, steam hammer, Diesel engine, et cetera, are social inventions relative to:

Tax system	Fundamentalism
Jury trial	Law schools
Wearing apparel	New wants
League of nations	International trade
Traveling libraries	Alumni
Accident prevention	Crime prevention
Capitalistic system	Poverty
Medicine	Political platforms
Graft	Racial accord
Legal service	Court procedure
Weights and measures	The work of assessors
Value of the dollar	Investment
War	Waste of metals
Minorities	Overcrowded professions
International language	The "funnies"
Distribution of wealth	Rackets
Noise	Simple life
Health	Pedestrianism
Motivation of production	Liquor control
Disarmament	Form of government
Idle time	Red tape
Worry	Automatic referenda
Personal insulation	Judgment test for voters
Duplication	Education
Advertising	Rumor damper and lie sterilizer
Tariff	Conservatism
Cities	Rotation of occupation
Wild life	Travel
Jobs	Community buying and use
Discovery of law breakers	History
Regulation of production to need	
Moral code	

Along with inventions of which the above tangential terms are but obscurely suggestive, there should be a social invention to prevent interference with the work of social invention, interference by which the uninformed may harass and bedevil the man of original mind. In mechanical invention we have reached a stage where it would simply be malicious mischief to break up the model or smash the shop of a man working on a new mechanical device. And while the trick of buying mechanical inventions and burying them is not unknown, it is not regarded with favor by impartial critics. But on the whole the mechanical inventor goes ahead freely whether in Tennessee or elsewhere, with no legislature to bother him, no pulpit to rail, no policeman as mentor. Such freedom should the social inventor have, or be

cramped in style. Unfortunately, the person with socially inventive ideas may now find himself as the early scientists and mechanical inventors found themselves—much disliked. All that needs to be changed, and with change would issue a flood of ingenuity from which, by a selective process, would come the big and little machines of social advance. The social inventor, otherwise thinker, or "radical," should be given a chance comparable to that enjoyed by the esteemed James Watt but denied the estimable Roger Bacon. We are now old in mechanics but primitives in social invention.

By this time the reader is perhaps experiencing a growing sense of difference between mechanical and social invention, and is becoming disposed to question the whole analogy. He sees that mechanical inventions concern things, while social invention involves people; but at a stage the two are alike—the stage of subjective creation. It is true that as soon as a mechanical invention is put to work, people are immediately and surely affected, and perhaps in large numbers. It will furthermore be observed that whereas the mechanical inventor has freedom of experimentation, the social inventor has no such freedom; he even finds that to style a political step experimental is to stigmatize it; experimentation has a status for mechanical invention, and quite another for social invention. Social invention is moreover denied an immediacy of fruition, unlike the mechanical, in that so many, especially voters, must be won over to the new thing before it can be set in motion under the laws. Inertia and ignorance in tracts of the public mind have to be overcome by the social innovation, while it is no bar to the initiation of mechanical improvements that the far-flung electorate is unready for change. The few who are at first interested in a new machine may choose to use it, which they are at liberty

to do, and without taking a popular vote on the principles of its construction.

Admitting, even parading, the differences between mechanical and social invention, yet one may insist on certain likenesses. The act of invention is the same in either case; the man who thinks out an economy of municipal administration or a basic plan like that of Henry George is an inventor, in class with "inventors." He has envisaged a difficulty and mentally surmounted it, through creative imagination.

As to need of social inventions—new ways, techniques, procedures, laws, arrangements, provisions and planning in education, justice, professions, economies, trade and world affairs, the social inventor is exigently required. The mechanical inventor has given us too many hats; the social inventor has not given us too many techniques and aids for social ends. The mechanical inventor has given us Chicago, and the lack of the social inventor has given Chicago its city government. The mechanical inventor gave New York City the Empire State Building, and the lack of social ingenuity leaves the city to Tammany. The mechanical inventors give us bombing planes, while Cro-Magnon politicians still chip flints.

Objection may still be raised that the perfection of social and political institutions will involve a degree of social intelligence beyond the possible. If political and social development require any material change in the level of native intelligence, then of course Utopianism is a dream. But does it? It might as well have been argued, prior to the many inventions of the machine age, that human intelligence would fail under the new burden. What happened was that millions learned about machines, which carried the machine age forward some distance, and that the foolproofing of machines carried the machine age forward yet farther. The machine has edu-

cated millions in the ways of machines; the automobile age has educated incredible millions to drive at locomotive speed to the tune of seconds and inches on railless roads.

Social inventions will educate their users, as the secret ballot has educated voters. A degree of foolproofing will also be necessary—the making of techniques easy for those who are always simple and for others who are simple in streaks, as able people usually are.

The egregious waste, hostility, vain running about and febrile pantomime, characteristic of the existing world disorder and economic anarchism, are com-

parable to the supine helplessness of man in his physical world but a few centuries ago, which has given way to confidence, sureness, conquest and research staffs associated with manufacturing establishments. The possibilities of social invention are as great as were the mechanical possibilities that lay before the early inventors of machines. The same vaulting intelligence is required for social invention as for invention in any field. Merely adaptation is required to effect on the social plane as large a transformation as was effected on the mechanical level by the science and invention of the past two hundred years.

SCIENTIFIC EXHIBITS AND THEIR PLANNING

By ROBERT P. SHAW

NEW YORK MUSEUM OF SCIENCE AND INDUSTRY

WITH the advancement of scientific knowledge and its far-reaching applications, people are becoming more "science minded" and interested in the underlying principles of the development and operating of the many facilities and conveniences placed at their disposal. A few decades ago a knowledge of history, art and literature constituted a liberal education. To-day an understanding of science is included in such a classification. With this increasing tendency of public interest in science and its applications, there has grown a need for popular science demonstrations and exhibits. In order for such exhibits to be effective in demonstrating to the public the growth and development of the various forms of pure and applied science, together with their utilization and social and economic results, a number of factors must be taken into consideration.

Various types of appeal should be emphasized in any exhibition of science. Important among these is the appeal of the exhibits to the familiarity of the

visitor with things he has already seen or with which he comes in contact during his daily life. It would be rather difficult for the average visitor to become very interested in some new scientific principle unless he could connect it with some practical application or something with which he is familiar. Important also is the appeal to the spirit of curiosity, both undirected and directed, as of a boy wanting to see all about television. Spectacular exhibits provide an appeal to the spirit of wonderment, exciting the imagination and arousing interest in the accompanying educational information. It is often possible to put over a rather technical idea by the use of a mysterious exhibit involving the same principle. There is the appeal to artistic sense which may include not only artistically designed or arranged exhibits or groupings, but also exhibits which are impressive because of the neatness or simplicity with which they operate.

Exhibits should, whenever possible, be dynamic rather than static. This is im-

portant, not only because of the stronger appeal to the visitor, but also because the whole spirit and subject-matter of science are dynamic and not static. Although the greater part of the exhibits should be presented in dynamic form, operating automatically or at the will of the visitor, they should be so planned as not to require an undue amount of attention for maintenance or demonstration. The scale of the exhibits and their arrangements should be such as to avoid an undue congestion of visitors around the dynamic exhibits. The exhibits should be chosen to attract people in all walks of life and of diversified interests. There should be exhibits for the more informed, as well as for those with less scientific background. As the main object of scientific exhibits is educational, truth should never be sacrificed in the interests of showmanship. Simple and striking ways can often be found for demonstrating principles which at first appeared too abstruse for possible presentation. There are some subjects



FIG. 1. HISTORIC RING OF SOFT IRON, WOUND WITH SEPARATE COILS OF COPPER WIRE CONNECTED TO BATTERY AND GALVANOMETER RESPECTIVELY. USED BY FARADAY IN HIS FIRST SUCCESSFUL EXPERIMENT IN ELECTROMAGNETIC INDUCTION.



FIG. 2. FARADAY'S "GREAT" ELECTROMAGNET.

WITH THIS HE MADE SOME OF HIS GREATEST DISCOVERIES, SUCH AS THE PRODUCTION OF ELECTRIC CURRENT BY THE ROTATION OF A COPPER DISC BETWEEN THE POLES OF A MAGNET; ALSO HIS DISCOVERY OF THE ROTATION OF THE PLANE OF POLARIZATION OF A RAY OF LIGHT, AND THE MAGNETIC AND DIAMAGNETIC PROPERTIES OF MATTER.

which can not be very intelligible to the average man, but which nevertheless are so important that they must not be entirely omitted.

Having considered a few of the aspects of scientific exhibits, the first step in developing an exhibition is to fix upon some sort of a general plan. Either a chronological development or some logical arrangement of the subject-matter, or a combination of both, may be used. In any case, there are serious objections to forced routings of visitors or allowing them complete freedom to wander at will through the exhibits. In order to meet these difficulties, it is advisable to group these exhibits into small units, with the most striking exhibit of the unit serving as the key exhibit. These units in turn are grouped



FIG. 3. PIECES OF MAGNETIC IRON ORE MAINTAINED IN ROTATION ABOUT VERTICAL AXES. THE COMPASS NEEDLE PLACED BETWEEN THEM INDICATES THE MANNER IN WHICH THE MAGNETIC FIELD CHANGES AS THE NATURAL MAGNETS ROTATE

into a larger unit or section, with the most striking exhibit serving as the key exhibit of the section. Continuing the same procedure, a number of sections are grouped into a division having its key exhibit. Thus, a visitor sees the most striking features of the divisions, sections and units in turn, and, if sufficiently interested, can examine the details of a unit without interfering with the main flow of visitors. Such a plan of flexible routings and key exhibits provides main and secondary lanes of travel for the visitors, depending upon

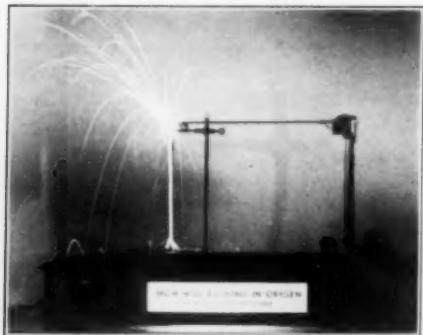


FIG. 4. THE CHEMICAL UNION OF IRON AND OXYGEN

IS ILLUSTRATED BY A RATHER FINE IRON WIRE FEED CONTINUOUSLY INTO A STREAM OF OXYGEN SUPPLIED BY A TANK UNDERNEATH THE TABLE.

the interest in certain exhibits or groups of exhibits. Another advantage of this plan is found in its flexibility to fit almost any type of architectural arrangement.

An exhibition of science and its applications may be well compared to a story, with the sections of the exhibit corresponding to the chapters, and the units of the exhibits to the paragraphs. By looking over the key exhibits, one sees the index of the chapters and gets a summary of the most important points.



FIG. 5. DOUBLE DECOMPOSITION IS ILLUSTRATED BY HEATING IRON OXIDE AND ALUMINUM, THUS REDUCING THE IRON AND OXIDIZING ALUMINUM. THE MOLTEN IRON POURS THROUGH A HOLE IN THE BOTTOM OF THE CUPEL INTO A VESSEL OF WATER UNDERNEATH.

As in the story, there should be a connecting thread running through all exhibits. Each exhibit to be most effective should answer satisfactorily the question, "Does it advance the theme or plot one step further?"

A properly balanced exhibition should consist of four types of exhibits: (1) Static exhibits, (2) continuously operating exhibits, (3) exhibits operated by the visitors, (4) exhibits demonstrated by attendants. There are no fixed proportions which can be used for these types of exhibits, as they vary with the nature of the subject, the expense involved in construction and operation

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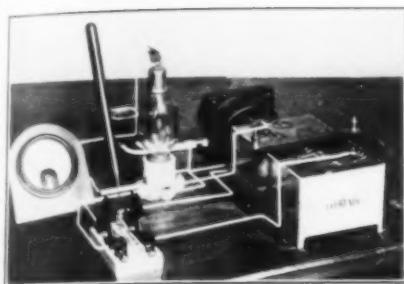


FIG. 6. AN EDISON EXPERIMENT.
WHEN EDISON WAS EXPERIMENTING TO PREVENT HIS LAMPS FROM DEPOSITING CARBON ON THE GLASS, HE PLACED A METAL PLATE NEAR THE FILAMENT AND DISCOVERED THAT A CURRENT OF ELECTRICITY FLOWS FROM THE HOT FILAMENT TO THE PLATE. THIS APPARATUS DUPLICATES THIS GREAT DISCOVERY THAT EVENTUALLY LED TO FLEMING'S VALVE, THE BEGINNING OF PRESENT DAY RADIO TUBES.

and with the scope and character of the exhibition.

The first type, static exhibits, generally is primarily historical in character. Fitting examples of this type are Faraday's ring and electromagnet shown in Figs. 1 and 2. These particular exhibits are very necessary in an exhibit of electrotechnology, for out of the simple experiments which Faraday performed with these and other pieces of apparatus have grown the science of electrical engineering and the great electrical industry as we know it to-day.

The continuously operating type of exhibit is very effective in drawing the attention of large groups of people and arousing their curiosity and interest. Such exhibits, to be most striking, should be made quite sizable and of a spectacular design. They should be placed in very prominent locations and should be made as dramatic as possible, with proper illumination and other effects. Ideal examples of this type are the three scientific exhibits shown in Figs. 3, 4 and 5. These, together with many other scientific demonstrations, have been developed by the Department of Exhibits of the Century of Progress International Exposition, Chicago, 1933.

The visitor operated type of exhibits is very suitable in demonstrating scientific principles and their applications to the visitors individually. In order to be most effective, they should present the idea as simply as possible and they should be made to operate without complicated controls and with the least amount of effort by the visitor. Two examples of this type are shown in Figs. 6 and 7.

The fourth type of exhibits requiring demonstration is the most spectacular. These, however, are rather limited in exhibitions of science from the standpoint of expense for operators. Accordingly, they should be restricted to those things which need attendant operation to make spectacular or for safety requirements. At the Annual Radio Show held last fall in New York, the New York Museum of Science and Industry gave periodic demonstrations with a large static machine and high frequency generator which proved very interesting and instructive to many thousands of visitors.

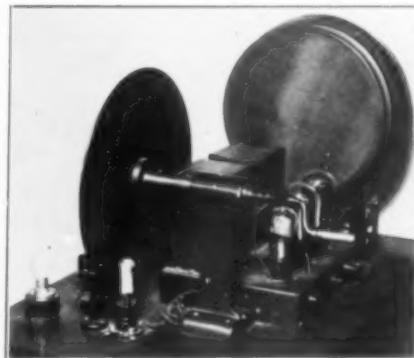


FIG. 7. PRINCIPLE OF TALKING PICTURES.

WHEN LIGHT PASSES THROUGH THE SOUND TRACK ON MOTION PICTURE FILM, WHICH IS REPLACED BY THE HOLES IN THE ROTATING DISC OF THIS APPARATUS, IT VARIES IN BRILLIANCE ACCORDING TO THE VARIATIONS OF THE SOUND TRACK. THE LIGHT IS FOCUSED ON A PHOTOELECTRIC CELL WHICH CHANGES THE LIGHT VARIATIONS TO VARIATIONS IN A WEAK ELECTRIC CURRENT. THE AMPLIFIER STRENGTHENS THIS CURRENT SO THAT IT CAN OPERATE THE LOUD SPEAKER WHICH PRODUCES SOUND WAVES.



THE EXECUTIVE COMMITTEE OF THE SIXTH INTERNATIONAL CONGRESS OF GENETICS

C. C. Little L. C. Doss D. F. Jones H. Demerec
R. M. Bassi T. H. Morgan G. H. Darlington R. A. Emerson

THE PROGRESS OF SCIENCE

THE GENETICS CONGRESS AT CORNELL UNIVERSITY

THE Sixth International Congress of Genetics met from August 24 to August 31, inclusive, at Ithaca, New York. Approximately 550 members registered. These, with the accompanying members of their families, brought the total attendance at the congress to about 800. The foreign delegation was, in spite of the world-wide economic stringency, representative and highly satisfactory. The leaders of the foreign delegates designated formally by their respective governments were as follows:

Belgium: M. le Professor L. Frateur and M. le Professor R. Vandedries. *Chile*: Señor Don Manuel Elgueta y Guerín. *Denmark*: Professor Dr. Ojvind Winge. *Finland*: Professor Harry Federley. *France*: M. le Professor A. Vandet. *Great Britain*: Professor R. Ruggles Gates, Ph.D., F.R.S., and Professor F. A. E. Crew, D.Sc., Ph.D. *Italy*: Professor Alessandro Ghigi, Professor Cesare Artom, Professor Fabio Frassetto, and Professor Corrado Gini. *Norway*: Professor Dr. Otto Lous Mohr. *Spain*: Señor Don Antonio de Zulueta y Escalano.

Beginning on August 25 the mornings were devoted to invitation meetings, at which the following topics were treated:

GENERAL SESSIONS

- "Mendelism in Man."
- "Inheritance of Educability."
- "The Use of Mosaics in the Study of the Developmental Effects of Genes."
- "The Present Status of Maize Genetics."

MUTATIONS

- "On the Potency of Mutant Genes and Wild-type Allelomorphs."
- "Mutations of the Gene in Different Directions."
- "The Genetic Nature of Induced Mutations in Plants."
- "Further Studies on the Nature and Causes of Gene Mutations."

THE INTERRELATIONS OF CYTOLOGY AND GENETICS

- "The Interrelations of the Genotype and the Karyotype and Their Bearing upon Some Genetic Problems."
- "The Cytological Basis for Crossing-over."
- "Neuere Ergebnisse über die Genetik und Zytologie des Crossing-over."
- "The Nature of Sex Chromosomes."

SPECIES HYBRIDS

- "The Species Problem in *Datura*."
- "Konjugation der artfremden Chromosomen."

CONTRIBUTIONS OF GENETICS TO THE THEORY OF ORGANIC EVOLUTION

- "Genetik der geographischen Variation."
- "The Process of Evolution in Cultivated Plants."
- "The Evolutionary Modification of Genetic Phenomena."
- "Can Evolution be Explained in Terms of at Present Known Genetic Causes?"
- "The rôles of Mutation, Cross-breeding, Inbreeding and Selections in Evolution."

Among the most important features of the congress was the series of exhibits. This was divided into many sections, the chief of which were the live plant exhibit, under the supervision of Dr. R. A. Emerson, and the laboratory exhibits. Dr. M. Demerec, as chairman of the exhibits sub-committee of the council, set a new standard of completeness and effectiveness in the preparation of material. It was the unanimous opinion of those in attendance that the graphic representation of the most recent advances in experimental genetics was both sensational and of the greatest scientific interest. The enormous spread in varieties of material successfully utilized to investigate the different genetic problems bears impressive witness to the progress made during the past three decades.

This fact was also brought out in the interesting and challenging presidential address delivered to a large audience on the evening of August 25 by Dr. Thomas Hunt Morgan. At this session the greetings of Cornell University were most happily conveyed to the delegates by Provost A. R. Mann. The response for the delegates was delivered by Dr. Richard Goldschmidt, of the Kaiser-Wilhelm Institut, who spoke with great wit and suitability.

The afternoons, beginning on August 27, were taken up by a series of sectional meetings at which a total of over 200 papers were delivered. The sections may be enumerated as follows: General Genetics 2, Cytology 3, Animal Genetics 1, Human Genetics 1, Method of Technique 1, Genetics and Phytopathology 1, Plant Genetics 1, Chromosome Structure and Crossing-over 1, Genetics of Species Hybrids 1, Drosophila 1, Problems relating to Sex and Fertility 1, Genetics and Pathology 1, Fruit and Vegetable Breeding.

The last named section was held at Geneva under the auspices of the New York Agricultural Experiment Station. At this session a full day's program was offered. The address of welcome was delivered by Director U. P. Hedrick. The station offered a dinner and entertainment for the visiting delegates.

The program of the congress was so arranged as to allow opportunity for informal meetings in the evening of groups with a common interest. Meetings to discuss sire valuation, corn genetics, mouse genetics, human heredity, poultry linkage and gene problems were held.

During the week there were two plenary sessions of the congress. At the first of these, three committees were appointed as follows:

Committee on Resolutions: H. Federley, chairman, R. R. Gates, C. L. Huskins, A. F. Shull,

Curt Stern, N. Vavilov, R. Vandendries, A. de Zulueta.

Committee on Greetings to Absent Colleagues:

G. H. Shull, chairman, C. Gini, O. Winge.

Committee on Nomination of Permanent International Committee:

T. H. Morgan, chairman, K. Bonnevie, F. A. E. Crew, G. P. Frets, A. Ghigi, H. Nachtsheim.

Besides a complete and interesting program for visiting ladies there were many informal social events. These began with a dinner in New York City at the Hotel Waldorf on the evening of August 23. At this dinner the visiting foreign delegates were the guests of the Carnegie Endowment for International Peace. The speakers were Dr. Thomas Darlington, representing the City of New York, T. H. Morgan, C. B. Davenport, J. B. S. Haldane, Kristine Bonnevie, R. Goldschmidt and N. I. Vavilov. Greetings were read from E. B. Wilson, who was absent on account of illness. At Ithaca, an informal reception, at which the reception line consisted of Provost A. R. Mann and the members of the executive council of the congress, was held on the first evening of the congress. On the third day a picnic at Taughannock Falls State Park was attended by approximately 800. Indians from the nearby reservation entertained the group by tribal dances. Group singing was also a part of the program. On Sunday, August 28, many of the members went to Niagara Falls on an all-day excursion. For those who remained at Ithaca an organ recital was offered by D. H. Jones, organist of the Westminster Choir School. Excursions to Watkins Glen State Park and to Enfield Glen State Park completed a varied and attractive program. At the close of the congress a number of the delegates were guided on a trip to several New England institutions, while others scattered to visit in Canada and the Middle West.

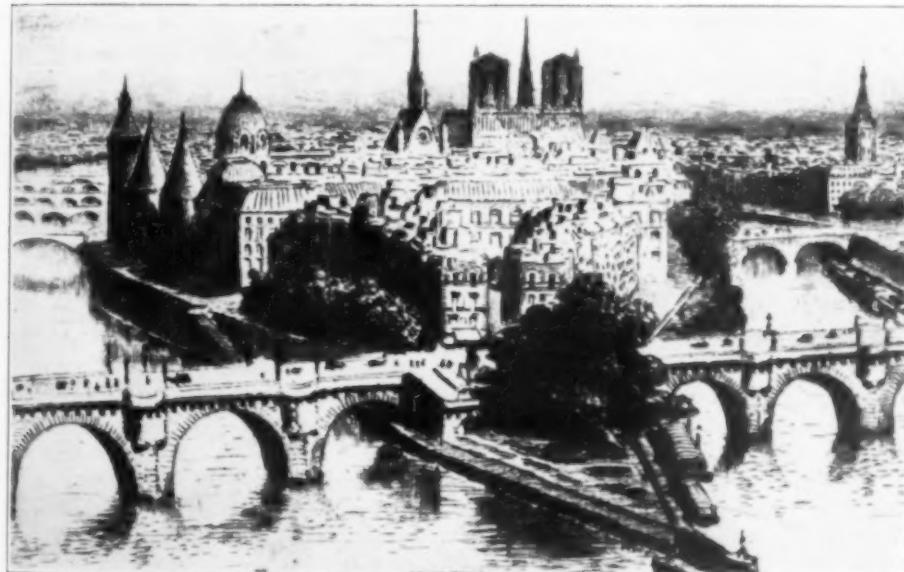
C. C. LITTLE

THE INTERNATIONAL ELECTRICAL CONGRESS AT PARIS

FRANCE has for centuries been one of the exponent and champion nations for world science, as well as for art and literature, the herald of the imaginative spirit. Except during the calamitous world war, hardly a year has passed, since 1800, without seeing at least one scientific congress assemble in Paris. Her International Electrical Congress of 1932 (July) was but the latest of a notable series of similar Paris electrical congresses held in 1881, 1889 and 1900, each of which was convened in conjunction with a world's fair, or "Exposition universelle." This congress of 1932 was actually one year behind its schedule; because it had been intended for 1931, as a jubilee or semicentennial commemoration of its famous predecessor—the Paris International Electrical Congress of 1881; but so many scientific world events occurred elsewhere in 1931 that this congress had to be postponed until 1932. Pressure on the calendar will sometimes distort a semicentennial period into a lapse of fifty years plus one. These

two Paris congresses of 1881 and 1932, being in historical apposition, may be designated as the Memorial and Jubilee congresses, respectively.

As is generally admitted, the main purpose of an international scientific congress is to invite a number of papers or "reports," perhaps a year in advance, from well-known specialists in various countries, on subjects of general interest, and to assemble the writers with a suitably large audience, for the reading and discussion of the same. These papers and discussions, subsequently collected and printed, establish a historical record of the state of that science and its applications, at the date of the symposium. A valuable by-product of such a congress comes, however, from the mutual interest and stimulus of personal contacts between workers in the same field of knowledge and research. The participants receive a renewed incentive, as well as an invigorating pleasure, in meeting and in exchanging views upon matters of mutual concern.



THE CITY OF PARIS



THE TROCADERO

AS SEEN THROUGH THE BASE OF THE EIFFEL TOWER.

The spirits of enterprise and of mutual veneration for the overworld are quickened by the associated mental effort.

At the Jubilee Congress, about 240 papers were presented, already printed in French, from representatives of some thirty nations. They had been received in several languages; but those not written in French were translated into that language by the secretariat. The discussions were likewise offered in several languages; but were all finally collected in French for the proceedings. It is expected that these proceedings, comprising both papers and discussions, will be distributed before the end of this year, in complete sets of fourteen or fifteen volumes, containing, in the aggregate, about eight thousand pages of text. Since the papers ranged in topic from the quintessence of modern electrical theory to perfections of technological detail, these sets of proceedings will constitute an electrical milestone for the first third of this century, of great theoretical, practical and historical interest.

The work of the congress was divided into thirteen sections. Of these, three or four dealt with basic electromagnetic

science, and the remainder with electrical applications. During the week occupied by the sessions, several sections were ordinarily at work simultaneously, in the same building.

In 1881, at the date of the Memorial Congress, the applications of electricity were virtually limited to electroplating on metal, telegraphy by wire and arc lighting. Wire telephony was then only in an incipient stage, and incandescent electric lighting had just commenced on a small but very promising scale. The great American inventor, Edison, had produced his first successful incandescent lamp in 1879, by indomitable courage and persistence. He was exhibiting a group of them at the Paris Exposition of 1881, together with what was at that time a very large Edison dynamo-electric generator. The electric switch, now so familiar in most households, for controlling all sorts of domestic appliances, was then rarely seen, except in scientific laboratories and in telegraph offices. Electric traction, electric motor driving, x-rays and radio-communication did not exist; so that many more applications had to be dealt with at the jubilee meet-

ing than at the memorial gathering. In 1881, the subjects discussed were essentially scientific, professional and remote from public attention. In 1932, owing to the wide-spread use of electricity in recent decades, the discussions, although still scientific, come much nearer to every man's door.

The outstanding contribution of the 1881 congress was the international establishment of certain electrical units of measure, which have since been universally adopted, and have even been incorporated into the legislative enactments of most countries. A few of them, like the volt and the ampere, are almost household words. The full list of 1881 contains five practical electrical units: the ohm, ampere, volt, coulomb and farad, named, respectively after pioneer electrical researchers in Germany, France, Italy (Volta), France and England (Faraday). All these units, being based on the meter and gram of the international metric system, are simple and decimal in their use. It is generally admitted that the rapid extension of electric utilities in all countries since 1881 is partly attributable to the simplicity and universality of these decimal connected units. Indeed, it may be said that the Jubilee Congress of 1932 bears testimony, in many ways, to the scientific foundations adopted and laid down at the Memorial Congress, and especially in regard to the methods of electrical measurement and computation internationally adopted in 1881.

A change of some importance seems to have come into the philosophy of electromagnetics, between the dates of

the Memorial and Jubilee Congresses, to judge by their respective literatures. In 1881, it would appear that mechanics and dynamics—*i.e.*, the properties of moving matter, as based on experiment—were regarded as fundamental sciences. Efforts were made at that time to link the conceptions of observed electric and magnetic phenomena with those of dynamics, in a subordinate way. In more recent decades, however, the discoveries of the electrical constitution of atoms, the doctrine of relativity and the doctrine of the equivalence between matter and energy have tended to displace dynamics from its central conceptual position and to replace it by electromagnetics. This change of thought does not alter any of the statements of the physical phenomena; but only the perspective of their conceptual relations. It seems likely that the next fifty years will also witness some interesting philosophical changes of view-point in electrophysics.

Out of the hundreds of members attending the Jubilee Congress, one, and apparently only one (in the German delegation), had also officially attended the Memorial Congress 51 years before. He was naturally the recipient of many congratulations.

The congress unanimously elected as its president Dr. Paul Janet, member of the Institute of France and director of the École Supérieure d'Électricité at Paris.

Beautiful weather aided hospitable Parisian hosts to make the visit memorable socially as well as scientifically.

ARTHUR E. KENNELLY

THE DENVER MEETING OF THE AMERICAN CHEMICAL SOCIETY

THE eighty-fourth national meeting of the American Chemical Society was held in Denver, Colorado, from August 21 to August 26. It was very well attended by chemists and their families from every part of the United States and

from at least one foreign country, China being represented by Dr. P. N. Woo, of Shanghai. There was a total of 916 officially registered members and guests, a surprisingly large number in view of the distance of Denver from the center



PROFESSOR ARTHUR B. LAMB
OF HARVARD UNIVERSITY, PRESIDENT-ELECT OF THE AMERICAN CHEMICAL SOCIETY.

of population of members of the society and the times of economic stress in which the country now finds itself. Many chemists took advantage of the low railroad rates to come to Colorado for a vacation as well as to attend the convention.

The general arrangement of the program was approximately that usually followed in the society meetings, with the council meeting on Monday morning, a general program with papers from the various divisions on Monday afternoon, and the sixteen divisional meetings then beginning on Tuesday morning.

In the deliberations of the council, the topic which was most discussed was the unemployment problem. It was reported that the percentage of unemployed in the ranks of members of the American Chemical Society is much smaller than among chemists as a whole. The desirability of doing everything possible to alleviate the general situation was recognized, but it was felt that this could be more efficiently accomplished by the various local sections than by the national society.

The usual subscription dinner and entertainment was scheduled for Mon-

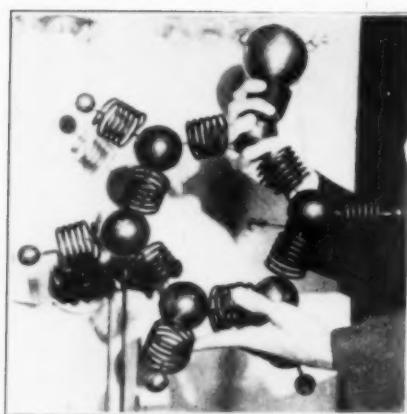


DR. CHARLES L. PARSONS

day evening. This proved to be unique in at least two ways. The first of these was the presentation of a jeweled American Chemical Society emblem and a sterling silver tea service to Dr. Charles L. Parsons, in recognition of his twenty-five years of faithful and invaluable service to the society as its executive secretary. The other variation was in the entertainment which followed the dinner. In addition to the customary dancing, one half of the banquet room, which had been curtained off during the dinner, was found to be a replica of one of the famous gambling halls which

flourished in Denver in the seventies. A number of professional gamblers were in charge and each guest was given a quantity of scrip with which he might try his luck at poker, roulette, chuck-a-luck and other games of chance. Prizes were awarded to those having accumulated, by fair means or foul, the largest amount of scrip at the end of a certain time.

A vacation was declared on Tuesday afternoon, and after being properly photographed, the entire group, about 1,250 in all, was loaded into cars provided by the local members and their



A MOLECULAR MODEL

OF MONOCHLORBENZENE CREATED BY PROFESSOR DONALD H. ANDREWS WHICH HE USED IN ILLUSTRATING HIS WORK.

friends. This motor cavalcade of some 400 cars then wound its way through Denver's scenic mountain parks, a distance of sixty miles, arriving in Golden, Colorado, about five o'clock. There Mr. Adolph Coors, Jr., head of the Coors Porcelain Company, entertained most royally in the form of a garden party on the spacious lawn surrounding his home. A fine dinner was served, after which the guests were allowed to choose among various types of entertainment ranging from visiting the company's porcelain factory, brewery or malted milk plant, to dancing, bridge or simply visiting with friends while listening to a splendid string orchestra. In addition to all this, each guest was presented with a souvenir in the form of a porcelain smoking set, embossed in gold with the society emblem.

To turn our attention now to the more serious side of the meeting, we find a total of nearly 300 papers presented in the various divisions. While it is perhaps difficult to pick out any one or two as the outstanding papers, taken as a whole the results of a vast amount of worth-while research were reported. Space permits the discussion of only a very few of these papers.

In the general meeting, one of the papers arousing considerable interest was the description and demonstration by Dr. Donald H. Andrews of his molecular models. These models were constructed of steel balls representing the atoms, with steel springs depicting the forces between them. On suspending these models by rubber bands and shaking them, it was found that each model vibrated markedly at three particular frequencies of shaking, and that these frequencies were more or less definitely related to the vibration frequencies of the molecules themselves as determined by their Raman spectra.

A symposium on the "Vitamin B Complex," under the auspices of the division of biological chemistry, attracted much attention. This vitamin, as brought out by Dr. H. C. Sherman, Dr. Robert C. Lewis and others, is evidently not a single substance, but includes several factors, probably at least seven in all, each of which contributes to the effects usually ascribed to Vitamin B. These various factors may be at least partially separated by their varying solubilities in alcohol, by preferential adsorption by fullers' earth and by other methods. Due to the variety of types of experimental animals used, it is not certain yet that all the factors reported are distinct entities, but it appears certain that there are more than the B and G (or B_1 and B_2) factors previously established. A number of other interesting studies of the rôles of various vitamins, as well as certain metals, in nutrition were reported. It might be mentioned in passing that Dr. C. G. King reported the isolation of Vitamin C in crystalline state and its identification as one of the hexuronic acids.

In the division of physical and inorganic chemistry, another symposium was held, "Metals" being the topic. Here the application of thermodynamics was emphasized. Dr. W. M. Latimer explained the use of ionic entropies in the

determination of electrode potentials of metals, especially those which do not readily lend themselves to the direct measurement of their potentials. Dr. C. G. Maier pointed out the use of thermodynamic data in determining optimum metallurgical conditions and also in improving present practices, while Dr. A. Wachter discussed the importance of thermodynamics in the study of solid solutions.

On Wednesday evening, a meeting open to the general public was held in the Denver Municipal Auditorium. At that time Dr. L. V. Redman, president of the society, was scheduled to give an address on "Some Economic Aspects of Research." Because of illness, he was unable to attend the convention, but Dr. Arthur B. Lamb, president-elect, read the paper which had been prepared by Dr. Redman. It emphasized the importance of continuing research during

times of depression as well as of prosperity, and urged the stabilization of methods of financing research in order that it may be so maintained. Dr. Lamb also presented the Priestley Medal to Dr. Parsons for his contributions to the advancement of chemistry, and the Langmuir Prize of one thousand dollars to Dr. Oscar K. Rice for his research on "The Theory of Unimolecular Gas Reactions."

Following the close of divisional meetings at noon on Thursday, a number of Denver plants were visited, and on Friday morning the delegates scattered to various parts of the state for additional vacation trips or departed for their homes. That they were satisfied with their visit to Denver has been indicated by the many expressions of appreciation and gratification which have come to members of the local committee.

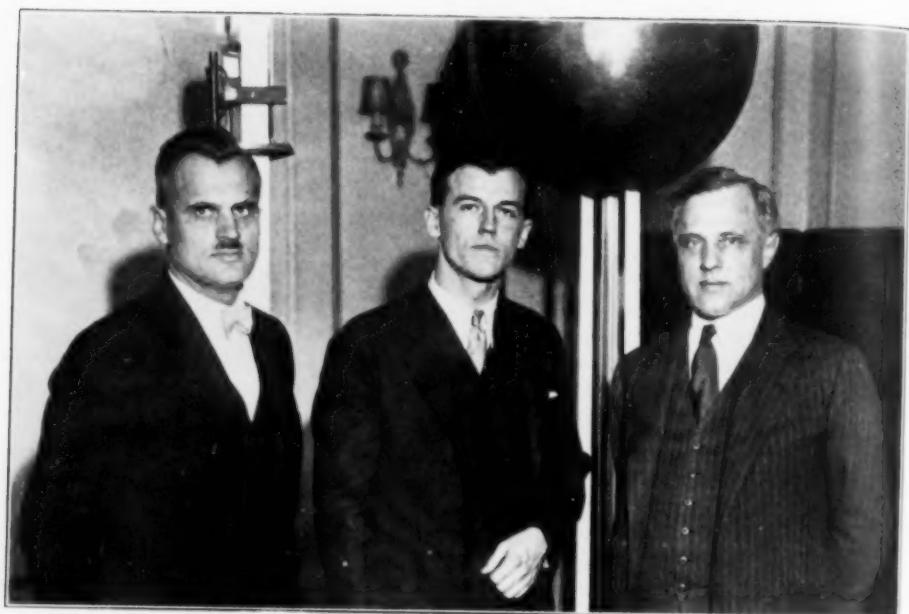
CLARENCE M. KNUDSON

AN APPARATUS FOR GENERATING HIGH VOLTAGES

CONSTRUCTION of apparatus to produce electric current of nearly 20,000,000 volts has been undertaken by Dr. Robert J. van De Graaff, research associate at the Massachusetts Institute of Technology. He has already built apparatus which produces a direct current of 1,500,000 volts. The machine he is now designing is expected to generate between 15,000,000 and 20,000,000 volts, with the ultimate possibility that 30,000,000 volts of direct current may be produced. In discussing the possibilities of this new method of generating electrical energy, Dr. Karl T. Compton remarked that no one can be certain just what the apparatus will do, but that it opens up new fields for scientific research and that a number of projects had already been outlined for investigation.

The necessity for having a very large building in which to house the new apparatus led Colonel E. H. R. Green

to offer the airship dock on his estate at Round Hill, Massachusetts, where, for several years, the institute has been carrying on an extensive research program. Dr. van De Graaff's experimental generator is a comparatively simple device consisting of two brass spheres two feet in diameter which are supported and insulated from the ground by glass rods. In each sphere a belt of silk, operated by a motor at the base of the supporting rod and running over a pulley within the metal globe, conveys the electric charge to it. Here it is stored, much as the human body stores electricity generated by the rubbing of shoes on a carpet. Instead of being produced by friction, however, the charge is "sprayed" on the silk belt by a "corona" or "brush" discharge. Although this voltage "sprayed" on the belt is comparatively low, the sphere becomes charged with higher and higher voltages as it picks up the stores of electricity brought to it



THE NEW APPARATUS FOR GENERATING HIGH POTENTIALS

WITH PROFESSOR ARTHUR H. COMPTON, DR. ROBERT J. VAN DE GRAAFF AND PRESIDENT KARL T. COMPTON, OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY. THE PHOTOGRAPH WAS TAKEN AT A DINNER MEETING OF THE AMERICAN INSTITUTE OF PHYSICS IN NEW YORK LAST SPRING.

by the belt. In the present 1,500,000-volt generator each sphere is charged with 750,000 volts. As an electric pressure of 1,500,000 volts is reached, sparks fly from the brass terminals.

The importance of this type of new generator is indicated by the fact that the highest potentials hitherto available for researches have been less than 600,000 volts. In only a few laboratories in the world is a direct current of more than 300,000 volts obtainable. In every case the apparatus producing such potentials is extremely expensive, elaborate and heavy, while Dr. van De Graaff's device costs but a few hundred dollars. The experimental model generating 1,500,000 volts was built for ninety dollars. In the apparatus at Round Hill the terminal spheres will be 15 feet in diameter, and it is hoped that this apparatus will develop at least 10,000,000 volts. Each will be mounted on towers

20 feet high and constructed to permit variation of the distance between them. The operator of the apparatus will sit within one of the spheres. His body, as well as the sphere, will be charged up to several million volts, but since he will be entirely surrounded by metal this tremendous charge will have no effect upon him.

Dr. van De Graaff's discovery is expected to extend the frontiers of research. The successful development of his generator on a large scale would make possible the projection of electrons and positive ions with velocities comparable to those of radium, but in quantities millions of millions of times greater than can be obtained from any radioactive source. This would place an effective tool in the hands of the physicist, making possible further studies of the transmutation of the elements.